A SURVEY AND EVALUATION OF ORGANIC COMPOUNDS IN NINE SEWAGE TREATMENT PLANT EFFLUENTS IN SOUTHERN ONTARIO

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PREFACE

The Ontario Ministry of Environment, with support from Environment Canada, undertook a survey of organic compounds discharged from selected sewage treatment plants in Ontario. Sewage treatment plants located in communities representing different populations and mixtures of industrial/domestic sewage were surveyed. This report describes the survey methods, outlines the analytical results of samples collected and discusses the significance of chemical information in relation to existing water quality criteria and objectives. In addition, a description and listing of fifteen current Ontario Ministry of Environment and Environment Canada programs is provided which describes other efforts to increase our knowledge in the areas of organics and sewage monitoring. It is recognized that a number of treatment improvements undertaken since the 1979 period of survey would likely alter the chemical profiles of these effluents.

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Summary

The Ontario Ministry Of The Environment (MOE) and the Environmental Protection Service (EPS) of Environment Canada conducted a survey in 1979 of nine sewage treatment plants in southern Ontario to identify and quantify the organic compounds in final effluents.

Analysis was limited to GC/MS identification of volatiles and solvent extractable compounds according to a set M.O.E. protocol. Only final effluent samples were analyzed.

Review of the 272 identified compounds indicated that the majority of organics were of limited toxicity, low persistence and would be restricted to the immediate discharge area. Nineteen compounds (seventeen of which are EPA priority pollutants) were highlighted after assessment of their biological accumulation potential, persistence and as a result of a unique correlation analysis of frequency-concentration occurance patterns. Benzene and derivatives, phenolics, chlorinated ethylenes and chlorinated ethanes scored the highest in the evaluation process and were identified for inclusion into surveillance, monitoring and abatement program development.

Conclusions

1. All plants discharged a wide variety of organic compounds at trace concentrations (less than 1.0 ug/l) with about the same frequency.

2. The frequency of discharge of compounds in the B and C (1-10 and 10-100 ug/l) concentration ranges was higher in primary treatment plants than in secondary and tertiary treatment facilities indicating a greater organic removal efficiency in the latter cases.

3. The frequency of discharge of compounds in the D (>100 ug/l) concentration range was low at all sites and was not dependent on degree of treatment.

4. Benzene and its derivatives followed by phenolics occurred most frequently in sewage treatment plant effluents. Chlorinated ethylenes, chlorinated ethanes and halogenated methanes were the next most common classes of chemicals.

5. The majority (80%) of organic compounds identified in this study are present in the final effluent of STPs near trace levels (<1.0 ug/l) and occurred with low frequency.

6. Available chemical information indicated that the compounds identified in the final effluents of sewage treatment plants occurred below estimated sublethal toxic concentrations for fish. Five compounds were identified as potentially bioaccumulative in biota.

7. Losses of the 19 compounds highlighted in this study were equivalent to the losses of the same compounds from similar sized industrial sources.

Significance of Findings

This screening study serves as a baseline inventory for contaminants surveillance of sewage treatment plant discharges and provides direction for abatement and research programs to protect receiving water quality. The analytical methods were non-routine in order to increase detection limits and to broaden the range of chemical identification thereby providing a wider and more indepth perspective of contaminants discharged.

A number of treatment improvements have taken place in several of the plants since 1979 which would be likely to alter chemical profiles of plant effluents.

During the evaluation of these results, a number of related research and monitoring programs have been initiated or modified in the Ministry of Environment and Environment Canada. The programs currently underway that address many of the research needs identified in this study are presented at the end of the report.

Comparison of chemical concentrations for the 19 compounds in the final effluent with provincial and international water quality criteria indicated that nine of the compounds highlighted exceeded one or other of those criteria.

While this report adds to the understanding of organics entering the Great Lakes and provides direction for future program planning it does not reflect ambient water quality or drinking water quality conditions. Ministry data from selected municipalities, eg. Metro Toronto, have not shown concentrations of chemicals to be of immediate concern to human health.

Extrapolation of data, in this study, to estimate concentrations of organics inside or outside the mixing zones of respective STPs must be recognized as speculative.

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INTRODUCTION

HISTORICAL SUMMARY OF SEWAGE DISPOSAL PRACTICES

The practice of sewage waste segragation can be traced back to Roman civilization but few if any advances in the technology were accomplish for centuries thereafter. In medieval Cambridge (England) raw sewage and the accompanying stench was common in public thoroughfares. It was not until 1401 that public health practices required weekly removal of raw sewage from the streets (Graham, 1966). Sewage disposal did not improve to any extent until the mid 1800s. The trend from leaving wastes in the streets was replaced by the use of privies which, as a result of seepage, contaminated ground water, wells and drinking water (Graham, 1966).

It became apparent that there was a direct relationship between the quality of drinking water and health. This relationship was recognized in 1893 as the Mills-Reinick phenomenon (Environment Canada, 1978).

In order to protect drinking water quality, hypochlorite of lime was added to water supplies. In Toronto in 1910, typhoid took 150 lives. Continued chlorination reduced typhoid deaths in Toronto to eight by 1922.

Conflicting water uses such as the discharge of wastes and the taking of drinking water or the development of recreational and swimming areas have by and large been avoided or reduced by separating respective discharge and water collection points. Water management practices, developed in the 1930's and 1940's could only provide limited protection of water quality before natural assimilation capacities of receiving waters would be exceeded. The discharge of raw sewage to lakes and rivers was essentially curtailed by the 1950s through the implementation of waste water treatment to improve receiving water quality in general.

Sewage treatment effectively improved receiving water clarity, reduced oxygen demand and in severe cases eliminated the associated odour of open water degradation of organic material. Later application of disinfectants such as hypochlorite of lime to sewage treatment plant effluents was instituted for further public health protection.

The realization that the manner of waste disposal and treatment directly and indirectly determined human and environmental health has been recognized only within the last 100 years. A better understanding of cause-effect relationships has provided direction in environmental program planning. This study was designed to identify and estimate the significance of organic compounds not routinely monitored or measured in environmental assessment programs.

CONTAMINANTS IN SEWAGE WASTES

Many organic compounds which enter sewage treatment plants are biologically degraded (Shamot and Mair,1980; Neufeld et al,1980). A brief overview of current sewage treatment plant processes are described in appendix 4. Organic compounds in general can be separated into three groups as follows:

1. Low molecular weight, aliphatics or aromatics such as acetone, ethanol and phenol which are easily biodegraded.

2. Compounds which can be degraded after biomass acclimation which include aromatic hydrocarbons or chlorinated short chain aliphatics such as benzene, carbon tetrachloride and 1,2-dichloroethane.

3. Compounds which are not extensively biodegraded even after bacterial acclimation such as dichlorobenzene and polychlorinated biphenyls (Thom and Agg,1975; Tabak et al,1981).

Nonhalogenated organic compounds that enter a sewage treatment plant may become chlorinated while passing through the chlorine contact chamber (Glaze, et al,1973; Smith et al,1974a; Smith et al,1974b; Glaze and Henderson,1975; Carlson et al,1975; Reinhard et al,1976; Murphy et al,1975). Prior to chlorination they may have little or no deleterious effect on the environment but in a chlorinated form may become a potential environmental hazard due to a change in chemical structure (Glaze et al,1973).

While there has been concern about trace organics in surface waters, surveillance and hazard evaluation has been hampered due to lack of appropriate analytical technology and resources. These limitations have been reduced by developments in gas-chromatography/mass-spectrometry (GC/MS) techniques, providing a practical tool for organic contaminant identification.

The EPA has identified 129 priority compounds of which 114 are organics (Keith and Telliard, 1979; Anthony and Breimhurst,1981). These compounds were selected on the basis of:

1) specific identification in the toxic pollutant list Table 2 in Keith and Telliard (1979)

2) frequency of occurrence in water (>= 5% of the total known listings for that class of compounds)

3) available chemical production data.

Compounds were given priority in pollution abatement programs designed to improve industrial effluents and receiving water quality. Regulations have also been established by the U.S. EPA, setting concentration levels of priority pollutants for industrial waste effluents discharged to municipal sewers (Ongerth and DeWalle,1980).

Since the Great Lakes waters are used as a major drinking water source and the near shore zone harbours many commercial and sport fish, identification and characterization of industrially related organic chemicals in these waters has been strongly supported by the public. Of particular concern are a number of chlorinated aromatic and aliphatic

hydrocarbons which have been identified as biologically accumulative, teratogenic, mutagenic and/or carcinogenic (Mullaney,1976; Tordiff and Deinzer,1973; N.R.C.,1978; Environment Canada,1978). Recent developments in GC/MS technology have made possible the characterization and identification of a large variety of organic compounds that might be found in water and in biota.

STUDY OBJECTIVES AND SCOPE

This screening study was designed to identify the presence and frequency of organic compounds discharged by selected sewage treatment plants in southern Ontario. Chemical data were to be evaluated to identify compounds that should receive priority in pollution abatement programs. Potential biological effects of some compounds found in discharges were to be estimated by the application of toxicity relationships.

Emphasis in this study was placed on effluents, while the potential sink for organics in sewage sludge was not addressed. Conventional organic pollutants such as pesticides and PCBs were also not included in the analytical survey as the study was designed to identify compounds of future concern.

The results of this study were intended to serve as a base line inventory for contaminants surveillance of whole plant discharges and a reference for future sewage treatment plant effluent studies.

METHODS

PLANT SELECTION

Plant selection was based on information amalgamated by the following groups: Ontario Ministry of The Environment (Water Resources Branch and Pollution Control Branch) Environment Canada (Ontario Region EPS, Water Pollution Control Directorate and the Wastewater Technology Centre).

The sewage treatment plants were chosen on the basis of the type of community, industry serviced and design capacity, allowing a representative cross section of sewage treatment plants to be sampled.

The Cornwall and Sarnia sewage treatment plants both employ primary treatment with phosphorus removal. The former receives wastes from heavy industry, manufacturing and an urban community while Sarnia's treatment facility handles effluent from a mix of urban and light industry.

Examples of conventional secondary treatment facilities are Goderich, Hamilton, Burlington, Kitchener, Toronto Main and Lakeview. The latter four plants also employ phosphorus removal. The Hamilton plant has been identified as having a high iron content in its influent. Consequently it does not require additional chemical coagulant in its effluent. Goderich processes mainly municipal wastes with virtually no industrial input. Kitchener and Lakeview process a mix of urban and light industrial effluent, while Hamilton and Toronto Main receive a variety of wastes from heavy industry, manufacturing and a large urban community.

The only tertiary treatment facility studied in this report was the Stratford STP which employs sand filtration with phosphorus removal.

The respective flow rates, design capacities and treatment type are presented in appendix 1. Performance parameters were recorded during sampling and presented in appendix 2.

EFFLUENT SAMPLING

All effluent samples were collected from a post chlorinated final discharge site. Samples were collected continuously at 3ml/min. over a 24 hour period for 7 days. Each 24 hour composite was collected in a 4 liter amber glass bottle with a teflon lined cap and housed in a refrigeration unit kept at 3 C. At the end of the seven days the seven 24 hour samples were composited in an acetone washed and dried glass cylinder, stirred with a glass rod and divided into three 4 liter bottles.

All equipment was acetone washed and dried in order to avoid contamination. Only glass, teflon or stainless steel materials were used. Sample bottles were cleaned with soap, rinsed twice, acetone washed (acetone distilled in glass) and baked in an oven at 75 C for 24 hours.

The size and design of the Toronto Main plant made it necessary to utilize the on site conventional composite sampling facilities. The sampling equipment had been in continuous operation for over a year, thus reducing concern for adsorption and cross contamination of compounds.

A teflon peristaltic pump was required at the Sarnia plant to draw samples up a 20 foot well and into the sample container.

Blanks of millipore treated water were passed through cleaned pumps and tubing before and after use to provide an indication of possible contaminant carry over. On three days of the week samples were taken for conventional chemical water quality parameters to indicate operational characteristics during organic sampling.

Relevant comments in terms of plant operations during the sampling period were also recorded. In addition to daily plant flows, the presence of chlorination, the use of process additives, the occurrence of accidents causing abnormal operation and the incidence of heavy rains were noted.

FISH COLLECTIONS

Fish were collected in the receiving waters adjacent the Toronto Main and Cornwall sewage treatment plants. Five samples of eight fish composites (yearling yellow perch Perca flavescens) were collected from Cornwall. Six samples of fifteen fish composites (young-of-the-year emerald shiners Notropis atherinoides) were collected from Ashbridges Bay (Toronto Main). Fish were collected using a sixty foot seine net having a 1/4" mesh. Fish lengths were recorded, scales were taken for aging and composites were then wrapped in hexane washed aluminum foil, labelled and stored separately in "whirl pak" bags. Fish composites were frozen in the field with dry ice. Prior to analysis composites were homogenized using a virtis homogenizer with stainless steel blades and bowl. The equipment was cleaned with acetone between samples to avoid cross contamination.

GC/MS PROTOCOL

All samples were concentrated prior to GC/MS separation and identification of the organics present. The volatiles were concentrated by a purge and trap technique, the trap being thermally desorbed into the GC/MS system. The extractable organics were concentrated by a continuous liquid/liquid extraction procedure using benzene as a solvent. The extract was then subjected to GC/MS analysis. Details of the methodology are outlined in appendix 3.

GC/MS PRINCIPLES

The following is a description of the procedures used in GC/MS analysis and interpretation:

a) Sample Concentration

In order to carry out GC/MS analysis of trace organic compounds the organics in the sample must be concentrated. This concentration step can be carried out by trapping volatile organics on a suitable medium or by transferring less volatile organics into a suitable organic

solvent. An internal standard is added to the sample during this analytical process. This standard is chosen as a compound which is unlikely to appear in any environmental sample. The purpose of its addition is to monitor that the conditions of the GC/MS analysis have not changed markedly. The standard also acts as an indicator for quantitative purposes since a known amount is added to each sample.

b) Analysis

After trapping or extraction, a portion of the sample is introduced to the GC/MS instrument. The gas chromatograph acts to separate the components of a complex mixture on the basis of the speed with which different compounds are able to pass through the column. Over a period of time, as each compound (or group of compounds) exits from the column, it is presented to the mass spectrometer. The molecules of the separated compounds are then ionized in the mass spectrometer producing a pattern characteristic of a particular compound or class of compounds. These patterns, called mass spectra, are stored in a computer together with the time during the analysis when they appeared.

c) Interpretation

Interpretation of the mass spectra is then required in order to identify the components present. A number of factors need to be considered including:

i) time of elution,

ii) the possibility of a mixture of compounds with quite different chemical characteristics appearing at the same time and yielding confused spectra,

iii) different compounds with the same elution time may give quite similar spectra,

iv) the possibility that the fragments seen can be reconstructed to yield compounds which are naturally occurring or introduced by normal human activity, by the sampling or by the analytical process as opposed to compounds of definite industrial origin.

The computer can assist in the interpretation by carrying out a comparison of the "unknown" to mass spectra of over 25,000 compounds stored in the computer library. In a very complex sample, manual interpretation has to be carried out by a skilled mass spectrometrist. This interpretation is based on the analysis of the mass spectrum obtained by the instrument together with a knowledge of organic and environmental chemistry to attempt to identify the compounds. The manual interpretation is usually done with reference to the library of over 25,000 compounds in the computer and to reference documents listing mass spectra obtained in other laboratories.

When a computer library search is carried out the normal requirements for an identification are a computer "fit" of greater than 80% with the library mass spectrum. On occasion, the mass spectra of a chemical class of compounds show general similarities and it is difficult to distinguish the members of that class. Such is the case when one considers aliphatic hydrocarbons.

The certainty of identification, in most cases is based mainly on the inspection of the mass spectra. Little other comparative analytical data is available for evaluation because of the wide variety of compounds observed by this technique, as in this case 272 compounds. In order to increase the degree of confidence in the identification an authentic standard must be analysed under identical analytical conditions. Many of the compounds identified as trace organics in environmental samples are not in fact available commercially as pure compounds suitable for standards.

This manner of interpretation is an accepted approach and is classified as level II in terms of confidence level in a document entitled "Master Scheme for the Analysis of Organic Compounds in Water-Interim Protocols" prepared by Analytical Sciences Division, Chemistry and Life Sciences Group, Research Triangle Instititute for the U.S. EPA.

The mass spectrometric response can be used for quantitative purposes as well as qualitative interpretation. This quantitation, however, is accurate only when authentic standards of the compounds identified can be analysed through the total analytical process. As described above there are difficulties in obtaining many of these compounds. In this study 18 such standards were utilized (see Table 1). An estimate of the quantity of a component present in a sample can be made based on the response (ion current) of the compound compared to that of the internal standard. In spite of the uncertainties recognized above, some basic assumptions are necessary in order to allow component quantification and ultimately to estimate and evaluate the impact of identified compounds. The main assumptions are:

i) The recovery of the compound in the concentration process is identical to that of the internal standard.

ii) The mass spectrometric response of the compound is identical to that of the internal standard.

iii) The GC behaviour of the compound is identical to that of the internal standard.

iv) The GC/MS response is linear with concentration.

v) A single component is present within a GC "peak".

vi) Complete extraction of the sample was achieved at the liquid/liquid extraction step.

vii)There was no loss of volatile organic contaminants during the 7-day composite sampling.

This last assumption in particular may be in doubt since it differs from the others (which relate to instrument performance) in that it reflects physical stability of the sample during collection.

The analysis for this project was carried out using packed columns in the GC portion of the system. The use of packed columns has since been superceded by the application of high resolution capillary columns. Packed columns may not have the resolving power to separate individual compounds in a complex matrix. In complex samples such as sewage

treatment plant effluents, the certainty of only one compound being present in a particular GC peak is low. In addition, the validity of the other assumptions is also unknown and consequently only a semi-quantitative estimate of concentration can be given.

Therefore the following concentration ranges were used to quantify the compounds identified.

Designated Concentration Range	Rank Score
A-<1.0 ug/l	A=1
B- 1.0-10.0 ug/l	B=2
C- 10.0-100.0 ug/l	C=3
D->100.0 ug/l	D=4

DATA TRANSFORMATION AND APPLICATION

Mean Rank Concentration

The interpretation of concentration range data bases (semi-quantitative) is difficult without scoring the ranges in a way that they can be used to calculate relative levels of impact. It was also considered important to express the results in terms of relative concentration levels to determine the priority of compounds based on frequency of occurrence and levels of concentration. Consequently the following procedure was used to calculate a "Mean Rank Concentration" (MRC) for compounds that were identified more than once at a concentration of 1 ug/l or greater and/or were an EPA priority pollutant.

1. The sum of rank scores (see above) for an individual compound (j) at a specific STP (i) was divided by the number of times (Y) that plant was sampled.

2. The above process was repeated for the same compound identified at all other plants.

3. The values computed were then summed over all plants.

4. The sum was divided by the number of plants (n) in which the compound was identified.

$$MRC = \left[\sum_{ji=1}^{n} \left[\frac{\sum_{k=1}^{m} X_{ijk}}{y_i} \right] \right] \cdot \frac{1}{n}$$

where:

- n = number of STP effluents in which compound j was identified (n is less than or equal to 9)
- X_{ijk} = the rank score (1,2,3 or4) that compound j was measured in plant i on the k sampling occasion
- m = number of times that compound j was detected in plant i effluent
- y_i = The number of times a plant was sampled

The MRC represents the mean concentration range score of a compound identified in the sewage treatment plant surveyed. Calculation of the MRC enabled ranking of compound concentrations and development of specific conclusions based on semi-quantitative data. High MRC values do not imply biological significance in terms of accumulation or toxicity.

Concentration Range Frequency Analysis

Since the number of samples collected from the various sewage treatment plants was not equal, a method of normalization was necessary in order to facilitate comparison among plants with regard to concentration range distribution. The normalization process averaged the frequency of occurrence for each concentration range based on the number of samples taken at each site. For example, in Table 1 the frequency of occurrence of the concentration range A at the Toronto Main treatment plant was found to be 11. This value was calculated by the addition of all the A concentrations for the volatile organics. This value was subsequently divided by 2 according to the number of samples collected for analysis, while the base/neutral and acid extractable organics total frequency of A concentrations was divided by 3 as three samples were analyzed. The same procedure was implemented on the remaining study sites. Although this method may slightly favour sites sampled more often, it does allow a relative comparison to be drawn among study sites in terms of the frequency of occurrence of the concentration ranges. The frequency distribution of the concentration ranges was also analyzed using the Chi square statistic for frequency data.

RESULTS

COMPOUNDS IN EFFLUENTS

A total of 272 organic compounds, including EPA priority pollutants were identified at all of the sewage treatment plants over all sampling periods (Table 1). EPA priority pollutants were tabulated separately (Table 2).

The Mean Rank Concentration (MRC) was calculated for compounds which were found more than once with a concentration > 1 ug/1 and/or were EPA priority pollutants (Table 3).

Methylene chloride was found to occur with high frequency resulting in a high Mean Rank Concentration (MRC) for this compound (14.5). However, methylene chloride, acetone, trimethyldodecatrienol and trimethyldodecatrienenitrile were regarded as artifacts of the extraction and cleaning procedure. For example a small residual of acetone in the collection bottles would result in a disproportionately high MRC. Methylene chloride is often present in the laboratory atmosphere and is registered by GC/MS during sample analysis. Consequently identification of methylene chloride is not considered a reliable indication of its presence in this study. The remaining two artifacts (trimethyldodecatrienol and trimethyldodecatrienenitrile) are used in hand creams and perfumes and may have been introduced through sample handling.

COMPOUNDS IN FISH

Table 4 lists the volatile organic compounds found in the Toronto Main effluent and in emerald shiners Notropis atherinoides collected in the vicinity of that STP as well as in the Cornwall effluent and in yellow perch Perca flavescens from adjacent receiving waters. Due to lack of appropriate analytical techniques at the time, fish samples were not analyzed for solvent extractable compounds.

Table 1: A Complete List Of Compounds Found At All Sewage Treatment Plants Over All Sampling Dates With Their Concentrations Given In Ranges As Follows: <1.0 ug/L-A; 1.0-10 ug/L-B; 10-100 ug/L-C; >100 ug/L-D

Volatile Compounds Identified	T[1]			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
* Methylene chloride	A	C	/	B	B	/	B	B	/	B		C	A	A		/	B		@
* Chloroform	B	B	/	B	B	/	B	B	/	B		B	B	B	B	/	B	B	@
* Dichlorobromomethane	A		/	A	A	/	A	A	/	A		A		A	A	/			@
* Trichloroethylene	A	A	/	A	B	/	A	A	/	B	B	B	B	A	A	/	A	B	@
* Tetrachloroethylene	A	A	/	A	C	/	A	B	/	A	B	B	C	A	A	/	B	B	@
* 1,1-Dichloroethane		A	/			/	A	A	/							/			
* 1,1,1-Trichloroethane		A	/	B	C	/	B	B	/			A	B		A	/		A	
* Trichlorofluoromethane			/	B		/			/					A		/			
* Chlorodibromomethane			/	B	B	/			/					A		/			@
* Chlorobenzene			/		A	/			/	A						/			@
* 1,1-Dichloroethylene			/		D	/		B	/			C				/	B	B	
* 1,2-Dichloroethane			/			/		B	/							/	A	B	
* 1,2-Dichloropropane			/			/		B	/							/	A	B	
* 1,1,2-Trichloroethane			/			/		B	/	B						/			
* Carbon tetrachloride			/			/			/			A				/			@
Benzyl chloride	B		/			/			/							/			
o-Chlorotoluene	B		/			/			/							/			
* Dichlorobenzene	B	B	/			/			/		B	B	C	B	B	/	A	B	
Methylchloroformate			/			/			/							/		C	
* Benzene	A	A	/	A	A	/	A	A	/	A	C	A	C	A	A	/	A	C	@
* Toluene	A		/	A	B	/	A	A	/	A	B	B	B	A	A	/	B	B	@
* Ethylbenzene			/		A	/		A	/		A	B	A		A	/	A	B	@
Xylene			/			/			/		B	C	C			/		C	
Xylene			/			/			/		C	C	C			/		B	
"Cumene"			/			/			/					A		/			
"Trimethyl benzene"			/			/			/					A		/			
a C9H12			/			/			/							/		B	
a C9H12			/			/			/							/		B	
Styrene			/			/			/							/		C	
a Mono terpene			/			/			/				B			/			
Saturated hydrocarbons			/			/			/			+	+			/			
Hexane		B	/		A	/			/					+		/	B	C	
Pentane			/			/			/		B					/			
Methyl butene			/			/			/					A		/			

Volatile Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
a C6H12		C	/			/			/							/			
a C6H12		B	/			/			/					A		/			
a C6H12		B	/			/			/							/			
a C7H14			/			/		A	/							/			
Trimethylpentene	B		/			/			/							/			
a C10H20			/			/			/						A	/			
Ethanol			/			/			/			C				/			
Isopropanol			/			/			/			C				/	B		
a C10H18O-"a terpineol"			/			/			/							/		A	
Diethyl ether	B	B	/	B		/		A	/	B					B	/			
Di-isopropyl ether	C		/			/			/			B				/			
a C5H12O (ethyl isopropyl ether)			/			/			/		B					/			
Propylene glycol			/			/			/							/		C	
Acetone	D		/	C		/			/							/	C		
Methylpropenyl ketone			/			/	A		/							/			
a C6H12O ("methyl pentanone")			/			/			/		C					/			
Dimethyl pentanone			/			/			/				C			/			
Ethylmethyldioxolane			/			/			/			B				/			
Carbon disulfide			/		B	/		C	/					A		/	C	B	
Dimethyl disulfide			/			/		C	/				C		C	/	C		
Extractable Compounds Identified																			
Aliphatic hydrocarbons	B		B	B			A							A	A	C	A	B	
Cycloheptadiene													A						
Methyl cyclopentadiene																	B		
Caryophyllene																	A		
Decahydro-1,1,7-trimethyl-4-methylene-1H-cycloprop(e)-azulene				A			A												
Substituted benzenes	A					B		A			A	B	B					B	
1-Cyclohexen-1-yl benzene																B			
Cyclopentyl benzene								A											
Cyclohexyl benzene				A		A		A								B	A		

Extractable Compounds Identified	T JUNE 19-25/79	T NOVEMBER 1-7/79	T DECEMBER 10-16/79	B SEPTEMBER 12-19/79	H SEPTEMBER 12-19/79	H NOVEMBER 22-28/79	St AUGUST 25-31/79	K SEPTEMBER 1-7/79	K NOVEMBER 22-28/79	L JUNE 19-25/79	L NOVEMBER 14-20/79	C AUGUST 10-16/79	C NOVEMBER 14-20/79	G AUGUST 23-29/79	G OCTOBER 24-31/79	G NOVEMBER 30-DECEMBER 7/79	S AUGUST 17-23/79	S OCTOBER 24-30/79	Standard Analyzed For Quant. Purposes
1-(t-Butyl)-4-ethenyl benzene				A															
1,1'-Methylene bis benzene								B											
Styrene																		A	
Methyl styrene																	A		
Styrene derivative					A														
Biphenyl													B		A		A		
Substituted biphenyl													B						
* Naphthalene																			
Substituted naphthalenes		A										B	B				+	(4)	
Tetrahydrodimethylnaphthalene																B			
* Phenanthrene/Anthracene												A	B					B	
Methyl phenanthrenes													B						
* Pyrene/Fluoranthene						B						A	B						@
Methyl pyrene													A						
Perylene						B													
PAH? MW 168												+	+						
PAH? MW 216													A						
Bicyclo (5,1,0) octane																	A		
Trimethyl bicyclo (7,2,0) undec-4-ene							A												
Tetrachloromethoxybenzene																	A		
* Hexachlorobenzene		A	A																@
Dichloronitrobenzene			A	A															
2-Methylbenzoyl chloride										B									
Chloroaniline				A												A			
Dichloroaniline						B						+	+	A		A			
p-Chloroanisole	A																		
* Pentachlorophenol	A																		@
Ethanol-2-chloro-propanoate										A									
1,1'-Oxybis-(4-chlorobutane)														A					
6-Chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine(simazine)			B																
Unidentified chlorinated														A			A		
1-Bromo-tricyclo(4,3,1,13,8) undecane							A												
* Phenol	B		B	B	B	A	A	A		B		C	C		B	A	B	C	@
Cresols												C	B					B	

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
Dimethyl phenols																		(2)	
Ethyl phenol											A								
Bis isopropyl phenol						A													
p-(t-Butyl) phenol	A		B	A							A			A					
Bis t-butyl phenol																			
Bis t-Butyl-4-methyl phenol																		A	
p-Octyl phenol	A		B	B				A	A	A			A	A	A	B		B	
p-Nonyl phenol				B														B	
Methoxybutyl phenol	A																		
Phenoxyphenol								B											
1,1'-Biphenyl-2-ol												B	B						
Biphenyl-4,4'-diol								A											
2-Ethyl-2-propyl hexanol														A					
2-Ethylhexanol												B	C						
2,2,4-Trimethylpentanediol															A				
1α,2β,5α,5-Methyl-2-(i-propyl) cyclohexanol								A											
Cyclodecanol														A					
3-Cyclohexen-1-ol																B			
3-Methyl-1,2-cyclopentadiol												B	+						
α,α,-4-trimethyl(s)-3-cyclohexene-1-methanol												B	C					C	
Trimethyldodecatrienol					B		A			B	B		B				A		
Benzene methanol													B						
2-Methyl-benzene methanol												+	+						
2,5-Dimethylbenzene-methanol										A									
2,4,5-Trimethyl benzene methanol										A									
2-/4-(1,1-Dimethylethyl) phenoxy/- ethanol												+	+					B	
Benzene ethanol															A				
1-Phenyl-1,2-butanediol												A							
Phenoxy alcohol												+	+						
Fenchone																		A	
Borneol isomer																		A	
1,3,3-Trimethyl-bicyclo (2,2,1)heptan-2-ol												A							

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
Oxy-bishexane													B						
1,1'-Oxybis octane														A					
Dimethoxyheptane									B										
3-Methyl anisole											A								
1-Isobutyl-4-ethoxy benzene																A			
Diphenylether													B						
Methyl phenyl pyranone												+	+						
Dibenzofuran					A														
Bis t-butyl furan																	A		
2,3-Dihydro-2-methyl-4-phenyl benzofuran																		B	
Tetrahydro-dimethyl benzofuran							A												
Tetrahydro-5-methyl-trans-2-furan methanol				B			A		A			+	+						
Dihydro-5-methyl-2-(3H) -furanone												B							
Isobenzofuranone												B	C						
Benzopyran-2-one													A						
Isobenzofurandione												+	+						
1H,3H-Naphtho(1,8-C,D) pyran-1,3-dione					B	A													
3-Ethyl-4-methyl -2,5-furandione															A				
Tetrahydro-2-(12-pentadecynyl-oxy-2H-pyran)								A											
Phenyl propanone												+	+						
9H-Fluorenone					A														
7H-Benz (D,E) anthracene-7- one					A														
9H-Xanthene-9-one												A							
Cyclohexadiene-dione					A														
9,10-Anthracenedione			A										B						
1,6-Dioxacyclododecane -7,12-dione										A									
1,5-Bis t-butyl-3,3-dimethyl bicyclo(3,1,0)hexane-2-one								A								A		B	

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
4H-Furo(3,2-G)-1 benzopyran-4,7,9-trione								A											
Substituted cyclohexanones	A																		
1-(3-Methyloxiranyl) ethanone							A												
2,4-Dihydroxy-6-methyl benzaldehyde			A																
1-Methyl-1-phenylethyl hydroperoxide	A									A									
8-Methyl-1,4-dioxaspiro (4,5)decane																A			
Benzoic acid												D	D						
Benzene acetic acid												+	A						
Benzene propanoic acid												+	+						
3-Methyl-2,6-dioxo-4-hexanoic acid				A															
Misc. carboxylic acids													C						
Methyl esters				A		B	A	B	B			C	C			A	B	A	
Ethyl ester hydroxybenzene acetic acid								A	A										
Butylester-2-methyl propanoic acid								A			A								
Di sec butylester succinic acid								A											
Misc. phthalates	D			A		A	A	A	A			B	C	A	B		A		
Methyl phthalate										A									
* Diethyl phthalate												B	B		A			B	@
* Dibutyl phthalate									A	A		B		A		B		B	@
* Dimethyl phthalate										A									
Monopentylphthalate										A									
* Dioctyl phthalate	C	A	C	B	B	C	B	B	B	B	B	C	C	B	B	C	B	B	
Misc.-O-containing		A	B	B	A	A	B	B	A		B	B	B	B	A	B		B	
Misc. steroid derivatives				B		C						+	+				A		
Androstane derivative								B											

Extractable Compounds Identified	T June 19-25/79	T November 1-7/79	T December 10-16/79	B September 12-19/79	H September 12-19/79	H November 22-28/79	St August 25-31/79	K September 1-7/79	K November 22-28/79	L June 19-25/79	L November 14-20/79	C August 10-16/79	C November 14-20/79	G August 23-29/79	G October 24-31/79	G November 30-December 7/79	S August 17-23/79	S October 24-30/79	Standard Analysed For Quant. Purposes
Cholest-3-ene							B	B				C	C					B	
Methyl cholestane													B						
Cholesta-3,5-diene				B				B				C	C		B		B	A	
Ergost-14-ene													B						
Cholestan-3-ol				B														B	
Cholest-8-en-24-ol													B						
2-Methylene-(3β,5α) cholestan-3-ol								A											
Cholest-ene-diol												+	+		B		B		
Cholestan-3-ol acetate												B	C		B				
4,5-Epoxy-(4α,5α) cholestane													B						
Androstan-1,4-diene-3,17-dione																		B	
11-Hydroxy-3-methoxy-(11)estra-1,3,5(10) -triene-17-one																		B	
3-Ethyl-3-hydroxy-5(α) -androstan-17-one												B							
Methyl ester-3-hydroxy cholan-2,4-dioic acid															B				
Heptylamine	A																		
α-Butyl-β-methyl-phenethylamine										A									
N,N-Dimethyl benzylamine	A									A									
1-(3-Aminophenyl) ethanone				A															
2-(Dimethylamino)ethanol												A							
O-Decyl hydroxylamine						B													
O-(1-Naphthalenylmethyl) -hydroxylamine								A											
* Nitrobenzene					A	A	A	B						A	A		A		
1-Methyl-4-nitrobenzene														A					
Nitropropylbenzene			A																

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
9,10-Dihydro-3-nitro-2-phenanthrylamine													A						
* Nitrophenol														A					@
Trimethyltridecatriene nitrile	B			B		B		B				B		B	A			B	
Tetrahydro-naphthonitrile				B														B	
Methylenepropane dinitrile					A	B								A	B		B		
1,1'-Biphenyl-2,2'-bicarbonitrile						B													
1-Isocyanatonaphthalene					A														
3,3'-Oxybispropane nitrile																		C	
3,3'-Iminobispropane nitrile																		B	
N-Propionyl butyramide										A									
N-(2-Hydroxyethyl) octanamide															A				
2-Methyl-N-phenyl benzamide								A											
N-Propyl benzamide												A							
N-Phenyl acetamide							A												
N-Isopropyl-N,3-biphenyl-2-propene amide	A																		
Amides				B				A				+	+						
N-(p-Methylphenyl)-1-aziridine carboxamide					A														
Methyl ester phenyl carbamic acid			A																
Benzene carbothioic acid												+	+						
Cyclopentanone oxime																	A		
1-Azido-3-methylbenzene																		C	
Diphenyldiazene		A	B																
1H-Indole																		C	
2,3-Dihydro-1H-isoindole																	A		
Methyl carbazole											A								
Morpholine											B								

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analyzed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
1-Methyl-1H-tetrazole											B								
1-Indoline carboxaldehyde													B						
3-(1-Methyl-1,2-pyrrol-idinyl)-pyridine (Nicotine)												B	B						
Pyrido-(3,4-D)-pyrimidin-4-3H-one												+	+						
N-Methyl-2-pyridinamine												+	+						
2-Methyl-2-phenyl aziridine			B																
3-Methyl-1H-1,2,4-triazole									A										
1,2-Dihydro-methyl-3H-indazol-3-one															A				
5-Methylpyrimidine																		B	
Piperazine													B						
Methyl pyrrazole													B						
9H-Pyrido (3,4-B) indole					B														
Phenazinol					A														
Imidazole derivative				A															
2-Pyrrolidinone																		A	
Benzo(H)quinoline																		C	
1-Ethyl-3-piperidinone			B																
2,3,4,9-Tetrahydro-1H-pyrid (3,4-β)indol-1-one																		A	
Imidazolidinone							A	A											
7,8-Didehydro-4,5-epoxy-3-methoxy-17-methyl(morphinan-6-ol)																		A	
Tetra methylpyrazine																		C	
2-Imidazolidinone										B	A								
Methoxyxanthenone					A														
2-Ethyl-4-phenyl-Δ,2,1,3,4-oxadiazolin-5-one			B	A										A			A		
Sulfur (as S)																		C	
Dimethyl trisulphide																		B	

Extractable Compounds Identified	T			B	H		St	K		L		C		G			S		Standard Analysed For Quant. Purposes
	JUNE 19-25/79	NOVEMBER 1-7/79	DECEMBER 10-16/79	SEPTEMBER 12-19/79	SEPTEMBER 12-19/79	NOVEMBER 22-28/79	AUGUST 25-31/79	SEPTEMBER 1-7/79	NOVEMBER 22-28/79	JUNE 19-25/79	NOVEMBER 14-20/79	AUGUST 10-16/79	NOVEMBER 14-20/79	AUGUST 23-29/79	OCTOBER 24-31/79	NOVEMBER 30-DECEMBER 7/79	AUGUST 17-23/79	OCTOBER 24-30/79	
s-Ethylester-thio-M-anisic acid									A										
1,1-Sulfonyl bis (2-methylbenzene)																B			
Thiazole derivative												+	+						
Benzothiazole			A							A									
2-Methylbenzothiazole			B					B											
2-(Methylthio) benzothiazole	A						A	B		A							A		
1,2-Benzisothiazol-3-(2H)-one																		A	
Benzenesulfonamide derivative																		A	
Methyl benzene sulfonamide	A		B								A			A					
N-Butyl-4-methyl benzene sulfonamide						B													
Methyl oxathiolane			A																
1-/(4-Methylphenyl) sulphonyl/-azetidine								A											
Tributyl phosphate											A								
Tri-octyl phosphate													B						
Triphenylphosphate																		B	
Caffeine	B		B	B	B		A	A	A	A	B	B	C	A	A	B	B	C	

+-present but unable to estimate quantity
1-T=Toronto Main
B=Burlington
H=Hamilton
St=Stratford
K=Kitchener
L=Lakeview
C=Cornwall
G=Goderich
S=Sarnia
*-EPA priority pollutant
/-dates for which samples are not available

Table 2: Compounds found in the STP effluent samples studied which are listed on the EPA priority pollutants list.

Compounds Purgeable / STP Site	Toronto Main June 19-25/79	Toronto Main Nov. 1-7/79	Toronto Main Dec. 10-16/79	Burlington Sept.12-19/79	Hamilton Sept.12-19/79	Hamilton Nov. 22-28/79	Stratford Aug. 25-31/79	Kitchener Sept. 1-7/79	Kitchener Nov. 22-28/79	Lakeview June 19-25/79	Lakeview Nov. 1-7/79	Cornwall Aug. 10-16/79	Cornwall Nov. 14-20/79	Goderich Aug. 23-29/79	Goderich Oct. 24-31/79	Goderich Nov.30-Dec.7/79	Sarnia Aug. 17-23/79	Sarnia Oct. 24-30/79
Benzene	■	■		■	■		■	■		■	■	■	■	■	■		■	■
Toluene	■			■	■		■	■		■	■	■	■	■	■		■	■
Ethylbenzene					■			■			■	■	■		■		■	■
Carbon tetrachloride												■						
Chlorobenzene					■					■								■
1,2-Dichloroethane								■									■	■
1,1,1-Trichloroethane		■		■	■		■	■		■		■	■		■			■
1,1-Dichloroethane		■					■	■										
1,1-Dichloroethylene					■			■				■					■	■
1,1,2-Trichloroethane								■		■								
Chloroform	■	■		■	■		■	■		■		■	■	■	■		■	■
1,2-Dichloropropane								■										■
Methylene chloride	■	■		■	■		■	■		■		■	■	■			■	
Dichlorobromomethane	■			■	■		■	■		■		■		■	■			
Trichlorofluoromethane				■										■				

Table 2: Cont.

Compounds / STP Site	Toronto Main June 19-25/79	Toronto Main Nov. 1-7/79	Toronto Main Dec.10-16/79	Burlington Sept.12-19/79	Hamilton Sept.12-19/79	Hamilton Nov. 22-28/79	Stratford Aug. 25-31/79	Kitchener Sept. 1-7/79	Kitchener Nov. 22-28/79	Lakeview June 19-25/79	Lakeview Nov. 1-7/79	Cornwall Aug. 10-16/79	Cornwall Nov. 14-20/79	Goderich Aug. 23-29/79	Goderich Oct. 24-31/79	Goderich Nov. 30-Dec7/79	Sarnia Aug. 17-23/79	Sarnia Aug. 17-23/79
Purgeable																		
Chlorodibromomethane				■	■		■			■				■				
Tetrachloroethylene	■	■		■	■		■	■		■	■	■	■	■	■		■	■
Trichloroethylene	■	■		■	■		■	■		■	■	■	■	■	■		■	■
Base/Neutral Extractables																		
Dichlorobenzene	■	■							■		■	■	■	■	■		■	
Hexachlorobenzene		■	■															
Nitrobenzene									■	■				■	■		■	
Di-n-octyl phthalate	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Dimethyl phthalate										■								
Diethyl phthalate												■	■		■			
Di-n-butyl phthalate									■			■		■		■		■
Fluoranthene												■	■					
Pyrene						■						■	■					
Phenanthrene												■	■					■

Table 2: Cont.

Compounds / STP Site	Toronto Main June 19-25/79	Toronto Main Nov 1-7/79	Toronto Main Dec 10-16/79	Burlington Sept 12-19/79	Hamilton Sept 12-19/79	Hamilton Nov 22-28/79	Stratford Aug 25-31/79	Kitchener Sept 1-7/79	Kitchener Nov 22-28/79	Lakeview June 19-25/79	Lakeview Nov 1-7/79	Cornwall Aug 10-16/79	Cornwall Nov 14-20/79	Goderich Aug 23-29/79	Goderich Oct 24-31/79	Goderich Nov 30-Dec 7/79	Sarnia Aug 17-23/79	Sarnia Oct 24-30/79
Base/Neutral Extractables																		
Anthracene												less than 1.0	1.0-10.0					1.0-10.0
Acid Extractables																		
Phenol	1.0-10.0		1.0-10.0	1.0-10.0	1.0-10.0	less than 1.0	less than 1.0	less than 1.0		1.0-10.0		10.0-100.0	10.0-100.0	less than 1.0	1.0-10.0	1.0-10.0	1.0-10.0	10.0-100.0
Nitrophenol														less than 1.0				10.0-100.0
Cresols												10.0-100.0	1.0-10.0					
Pentachlorophenol	less than 1.0																	

Concentration Ranges ug/l

- less than 1.0
- 1.0-10.0
- 10.0-100.0
- greater than 100.0

Table 3: Mean Rank Concentration (MRC) For Compounds Which Were Found More Than Once With A Concentration Of 1 ug/L Or Greater And/Or Which Were An EPA Priority Pollutant.

Compound	MRC	Compound	MRC
Benzoic acid	4.0	Methyl esters	1.4
Isobenzofuranone	2.5	Diethyl ester	1.4
2-Ethyl hexanol	2.5	Trichloroethylene	1.4
Dichlorobenzene	2.4	Toluene	1.3
Di octyl phthalate	2.2	Methylene propane dinitrile	1.3
Acetone *	2.2	Trichlorofluoromethane	1.3
1,1'-Biphenyl-2-o1	2.0	Pyrene	1.3
Dichlorobenzene	2.0	Isopropanol	1.3
Carbon disulfide	2.0	Phenanthrene/Anthracene	1.3
α-α-4-Trimethyl(s)-3-		Di-isopropyl ether	1.3
cyclohexene-1-methanol	2.0	Fluoranthene	1.3
3-(1-Methyl-1,2-pyrrolidinyl)		1,1-Dichloroethane	1.3
pyridine	2.0	Trimethyl dodecatrienol *	1.2
Dimethyl disulfide	1.9	Substituted naphthalenes	1.1
Xylene	1.8	Misc. phthalates	1.1
1,2-Dichloroethane	1.8	Diethyl phthalate	1.1
Cresols	1.8	Trimethyltridecatrienenitrile *	1.1
Cholest-3-ene	1.8	Ethyl benzene	1.0
Chloroform	1.7	Chlorobenzene	1.0
Tetrachloroethylene	1.7	p-Octyl phenol	1.0
Cholest-3,5-diene	1.6	Chlorodibromomethane	0.9
1,1,1-Trichloroethane	1.6	Substituted benzenes	0.9
Methylene chloride *	1.6	2-Methyl benzothiazole	0.85
Cholestan-3-ol acetate	1.6	Cholestene-diol	0.85
Phenol	1.5	Nitrobenzene	0.84
Hexane	1.5	Dichlorobromomethane	0.81
Cholestan-3-ol	1.5	Dibutyl phthalate	0.8
p-Nonyl phenol	1.5	Hexachlorobenzene	0.7
1,1,2-Trichloroethane	1.5	Carbon tetrachloride	0.5
Tetrahydro-1-naphthonitrile	1.5	Dimethyl phthalate	0.5
Benzene	1.4	Pentachlorophenol	0.3
		Nitrophenol	0.3

* - artifact

Table 4: Volatile Organic Compounds Found At Toronto Main And Cornwall Sewage Treatment Plant Study Sites And Their Respective Fish Samples.

	TORONTO MAIN		CORNWALL	
Compound	Effluent	Fish(ES)	Effluent	Fish(YP)
Methylene chloride	x	x	x	
Chloroform	x	x	x	x
Dichlorobromomethane	x		x	
Benzene	x	x	x	x
Trichloroethylene	x	x	x	
Tetrachloroethylene	x	x	x	
Toluene	x	x	x	x
1,1-Dichloroethane	x			
1,2-Dichloroethane		x		
1,1,1-Trichloroethane	x	x	x	
1,1-Dichloroethylene			x	
Dichlorobenzene	x	x	x	
Ethylbenzene		x	x	x
Acetone	x	x		x
Diethyl ether	x	x		x
Di-isopropylether	x		x	
Benzyl chloride	x			
Trimethyl pentene	x			
Hydrocarbons	x	x	x	x
Hexane	x	x		x
Hexanal		x		x
Dimethyldisulfide			x	x
Xylene		x	x	x
Carbon tetrachloride			x	
Ethanol			x	
Isopropanol		x	x	
Ethylmethyldioxolane			x	
Dimethyl pentanone			x	
Propanol		x		x
Pentane		x		
Pentanal		x		x
3-Methyl butanal		x		x
Hex-5-en-one		x		
2-Methyl-2-butenal		x		x
1-Octene		x		
2-Hexenal		x		
Heptanal		x		
2-Pentyl furan		x		
4-Methyl-2-butanal				x
Butanal				x
4-Methyl-3pentene-2-one				x

ES-Emerald Shiner
YP-Yellow Perch
x -Compound identified in fish samples

DISCUSSION

PREVIOUS STUDIES

The available literature provides limited information on the variety of trace organic compounds discharged from sewage treatment plants to receiving waters. A U.S. EPA priority pollutant survey of 60 publicly owned treatment works described the occurence and maximum/minimum concentrations of 90 organic and inorganic "priority pollutants" (EPA, 1982). An Environment Canada study (Zenon,1982) identified industrial sector sources of benzene, chloroform, chlorinated ethanes, chlorinated ethylenes, chlorinated phenols and polycyclic aromatic hydrocarbons in municipal wastewater. The frequency of occurrence of priority pollutants found by EPS (EPS, 1983) was similar to that found in this study. However, as in this study, quantification in the EPS report was limited to ranges.

Most studies describe specific chemical reactions such as the chlorination of organic compounds in chlorination chambers of sewage treatment plants (Carlson, et al, 1977; Bellar et al, 1974;Brown, 1978); or the chemical alteration of compounds between entry and discharge due to chlorination and/or biodegradation (Glaze and Peyton, 1977;Rockwell and Larson, 1977; Kleopfer and Failess, 1972; Anthony and Breimhurst, 1981; Randall and Knopp, 1980; Glaze et al, 1973; Ongerth and DeWalle, 1980).

Several studies have reported alteration of individual or classes of organic compounds in municipal sewage treatment plants. Brown (1978) and Bouwer et al (1981) suggested that halogenated 1 and 2 carbon compounds (C1 and C2) such as trichloroethylene, tetrachloroethylene, trichloroethane and chloroform were degraded by either bacterial or chemical processes while higher organohalides were more persistent. Dilling et al, (1975) identified that, because of their volatility, evaporation was probably the major pathway by which these C1 and C2 chlorinated solvents escaped from natural waters. Other workers have concentrated on members of specific groups of compounds such as PCBs,(Shannon et al, 1978) and identified only 1254 and 1260 Aroclor in the waste waters they studied, finding that primary treatment removed 50% of the PCB load while secondary treatment removed 66%.

While a wide group of compounds was identified in this particular study, pesticides, PCBs and mirex were excluded by the choice of analytical method unless present at levels greater than 5 ug/l.

PLANT OPERATIONS

Results indicated that Cornwall, Sarnia, Kitchener, Goderich, Lakeview, Toronto (Main), Stratford and Burlington were operating within normal limits and that the samples collected from these plants were representative of routine operation.

It was found that the effluent parameters BOD5 and SS at Hamilton were unusually high for November (appendix 2). Unusually high flow rates (57% above normal) were recorded during the September sampling period while November rates were 60% above daily averages for 1979. Heavy rains in the Hamilton area during the September sampling period may explain the higher flow rates. Consequently estimates for organic

concentrations may be lower than would normally be encountered and some organic compounds may have passed undetected. In June of 1979, the Hamilton plant was expanded to increase its capacity by 136,000 m3/day. However problems were experienced with equipment in the expanded plant which may have led to abnormal operations (Pers. Comm. plant manager).

Cornwall and Sarnia exhibited high BOD5 values during sampling, (appendix 2) compared to other plants sampled.

FREQUENCY DISTRIBUTION OF CONCENTRATION RANGES OF ORGANICS WITHIN AND AMONG PLANTS

The general frequency distribution of the concentration ranges of all compounds identified in the effluents is presented in Figures 1 to 4. It must be noted that the data in Figures 1 to 4 do not represent the number of compounds identified. If a compound was identified in more than one sample at a different concentration range the compound will be included in two or more of the above indicated figures.

Concentration Range <1.0 ug/1 (A level)

A slightly higher frequency of occurrence of compounds in the <1.0 ug/1 range was found in the effluent of the plants which have lower flow rates (m3/day) such as Kitchener, Goderich and Stratford (Figure 1). However there was no significant difference ($p>0.05$) in the frequency of occurrence of the A level compounds among the nine study sites. This indicates that all plants discharge low concentration compounds with similar frequency.

Concentration Range 1.0-10.0 ug/1 (B level)

The frequency distribution for the B level compounds (Figure 2) over all plants was significantly different ($p<0.05$). However when primary treatment plants (Cornwall and Sarnia) are removed from the calculations no significant difference was found.

Concentration Range 10.0-100.0 ug/1 (C level)

The frequency distribution for this concentration range suggests a higher efficiency in organic contaminants' reduction in secondary treatment plants over that of primary treatment facilities (Figure 3). When all plants are included in the chi square test a significant ($p<0.05$) difference is found among plants with respect to the frequency distribution of C level compounds. However as indicated previously, when primary treatment plants are removed from the calculations there no longer is a difference in the distribution.

Concentration Range >100.0 ug/1 (D level)

Compounds found at the D level (Figure 4) were only identified at Toronto Main, Hamilton and Cornwall. In Toronto Main's effluent acetone (probable artifact) and various phthalates were found; at Hamilton 1,1-dichloroethylene was identified in this concentration range; while in the effluent of Cornwall benzoic acid was identified. No significant ($p>0.05$) difference was found among study sites in terms of frequency distribution of D level compounds.

FIGURE 1: MEAN FREQUENCY OF OCCURRENCE OF THE CONCENTRATION RANGE A AT EACH STP

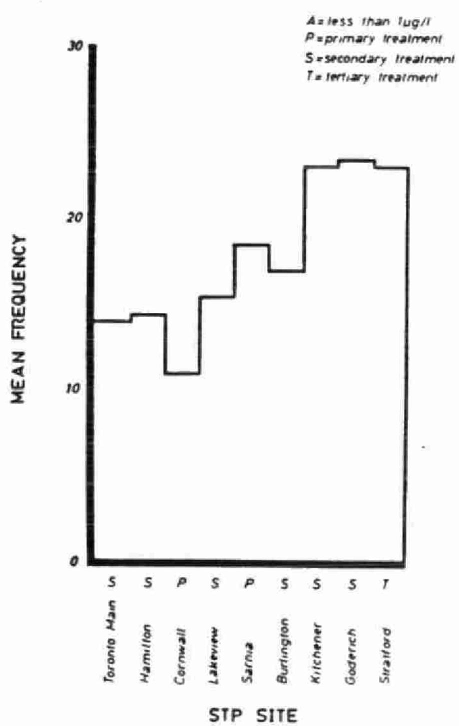


FIGURE 2: MEAN FREQUENCY OF OCCURRENCE OF THE CONCENTRATION RANGE B AT EACH STP

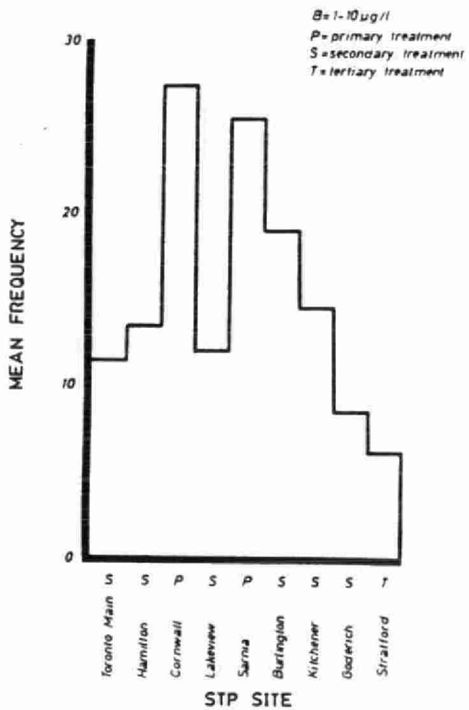


FIGURE 3: MEAN FREQUENCY OF OCCURRENCE OF THE CONCENTRATION RANGE C AT EACH STP

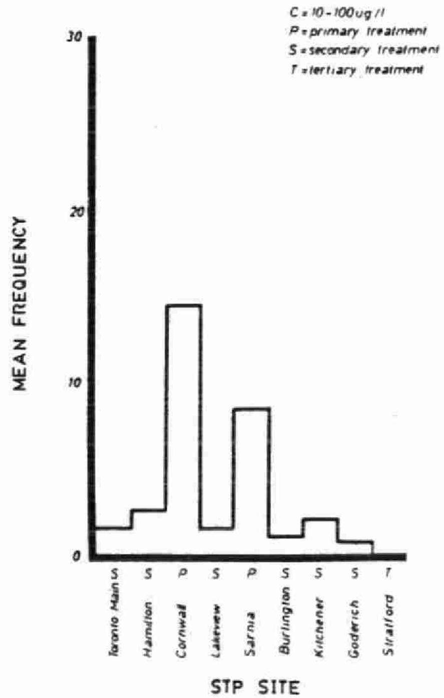
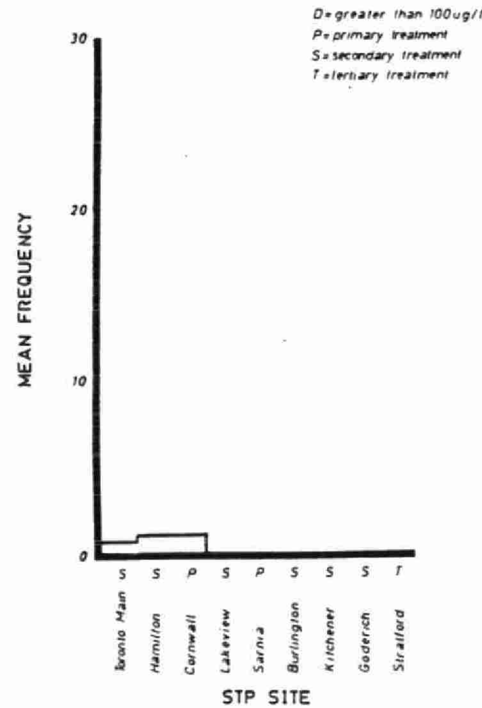


FIGURE 4: FREQUENCY OF OCCURRENCE OF THE CONCENTRATION RANGE D AT EACH STP



The following conclusions can be drawn from the frequency distribution of organic compounds at the different concentration ranges within plants.

1. All nine plants surveyed discharged a wide variety of organic compounds. The frequency of occurrence (number of compounds discharged) at less than 1.0 ug/L is similar in all plants.

2. There are significant differences in the frequency of occurrence of compounds (number of compounds discharged) at the 1.0-10 ug/L and 10 to 100 ug/L ranges Primary STP's had the highest frequencies at these two ranges, while the tertiary STP had the lowest fequency. Goderich, a secondary STP which recives mostly residential sources had slightly lower frequencies than the other 5 secondary STP's.

3. Only three organic compounds had been found to occur at greater than 100 ug/L concentration. Phthalates in the Toronto STP. 1,1-dichloroethylene in the Hamilton STP and benzoic acid in the Cornwall STP.

FREQUENCY OF OCCURRENCE OF SPECIFIC ORGANIC COMPOUNDS

Frequency of occurrence of compounds identified more than once with a concentration > 1.0 ug/1 and/or recognized as EPA priority pollutants are presented in Figure 5. A total of 62 compounds were identified with the remaining 210 compounds being identified only once during this study or near trace levels (less than 1 ug/1).

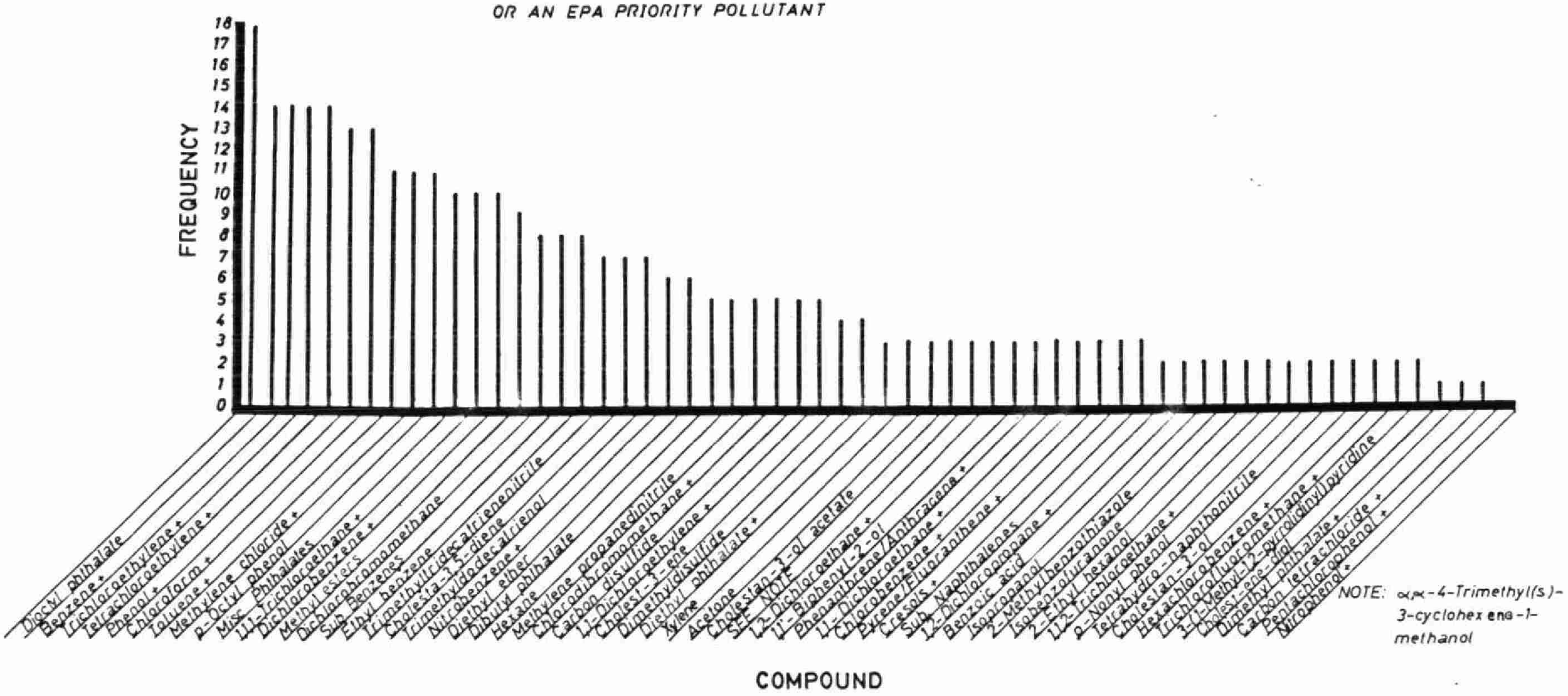
Compounds are grouped below according to their representative classes in order that associated uses might be more easily identified.

The major groups of compounds identified were:

1. Benzene and Derivatives: Benzene, benzoic acid, toluene, ethylbenzene, chlorobenzene, dichlorobenzene, hexachlorobenzene, nitrobenzene and 1,1'-biphenyl-2-ol represented 17% of the total Mean Rank Concentration (MRC) of compounds presented in figure 5 (table 3) while making up 19.5% of the total frequency. These compounds represent components of solvents, waxes, dyes, gasoline, styrene/rubber and as intermediates in the synthesis of other compounds.

2. Phenolics:
Phenol, octyl phenol, nitrophenol, nonyl phenol, pentachlorophenol and cresols represented 7% of the total MRC and 12% of the total frequency of compounds presented in figure 5. These compounds are used as disinfectants, insecticides and herbicides, used in the manufacture of synthetic resins and as additives in lubricating oils, resins and plasticizers.

FIGURE 5: FREQUENCY OF OCCURRENCE OF COMPOUNDS WHICH WERE IDENTIFIED MORE THAN ONCE WITH A CONCENTRATION OF 1 ug/l OR GREATER AND OR AN EPA PRIORITY POLLUTANT



3. Chlorinated Ethylenes:
Trichloroethylene, tetrachloroethylene, 1,1-dichloroethylene represented 6% of the total MRC and 9.5% of the frequency of figure 5. The majority of the loading of the chlorinated ethylenes was contributed by the Hamilton plant which from September 12-19,1979 had a mean composite concentration of organics >100.0 ug/1. These compounds are used mainly as industrial solvents.

4. Chlorinated Ethanes:
1,1,1-Trichloroethane, 1,1,2-trichloroethane, 1,2-dichloroethane and 1,1-dichloroethane make up 8% of the MRC and 6% of the frequency of compounds identified in figure 5. These chlorinated compounds are used as solvents in metal cleaning.

5. Trihalomethanes:
Chloroform, dichlorobromomethane and chlorodibromomethane. Work by Bellar et al, 1974 indicates that trihalomethanes are formed in the chlorine contact chambers of sewage treatment plants after a single addition of free chlorine. In this study chloroform made up 4.3% of the total MRC and 4% of the frequency of figure 5. Dichlorobromomethane and chlorodibromomethane were each estimated to represent 1% of the frequency and 1% of the total MRC of figure 5.

6. Human lifestyle indicators:
Nicotine was found in the final discharge of the Cornwall plant, while caffeine was identified at all the plants studied (table 1). Caffeine made up 1% of the MRC and 5% of the total frequency in terms of figure 5. Various organics found in the effluents are purely from industrial sources, such as the chlorinated ethylenes and may serve as markers for specific commercial operations, but caffeine and nicotine indicate that various organics may be linked to direct human inputs.

7. Artifacts:(Acetone, methylene chloride, trimethyldodecatrienol, and trimethyltridecatrienenitrile).
These compounds may be artifacts due to sample handling and may not be present in the STP effluent. As indicated in the methods, the sample bottles were rinsed with acetone while methylene chloride is ubiquitous in the laboratory atmosphere because of its widespread use as an extraction solvent and therefore may be present as a contaminant. The other compounds are found in hand creams and perfumes and may have been introduced during sample handling. Acetone and methylene chloride represented 2.5% of the RMC and 2.5% of the frequency of figure 5.

8. Remaining compounds presented in figure 5:
The remaining compounds in figure 5 account for 49% of the RMC and 36% of the total frequency of occurrence. These compounds constitute various groups such as human input (cholesterols and steroids), degradation products (isopropanol and 2-ethyl hexanol) and plasticizers (phthalates).

9. Remaining compounds not presented in figure 5:
The remaining compounds in this study were detected with low frequency and in low concentrations. This, however, does not exclude them from posing a detrimental effect on the receiving waters, but rather indicates the lack of hazard information currently available. These compounds represent 80% of the total 272 identified in terms of frequency of occurrence.

In conclusion:

1. Benzene and derivatives, followed by phenolics, were found to occur most frequently in sewage treatment final effluents.

2. The majority of organic compounds (80%) identified in this study are present in sewage treatment final effluents at trace levels (<1.0 ug/l) and/or occur with low frequency.

CONCENTRATION-FREQUENCY EVALUATION OF ORGANICS

In order to separate compounds according to their frequency of occurrence and relative concentrations, a ranking system utilizing both MRC and frequency of occurrence was applied to all compounds in Table 3 and Figure 5.

The compound with the highest MRC or frequency of occurrence was ranked as 1 and the compound with the second highest value in each category as 2 and so on. Compounds with equal MRC or frequency values shared mean ranks. The rank of each compound with respect to MRC was then plotted against its rank frequency (Figure 6).

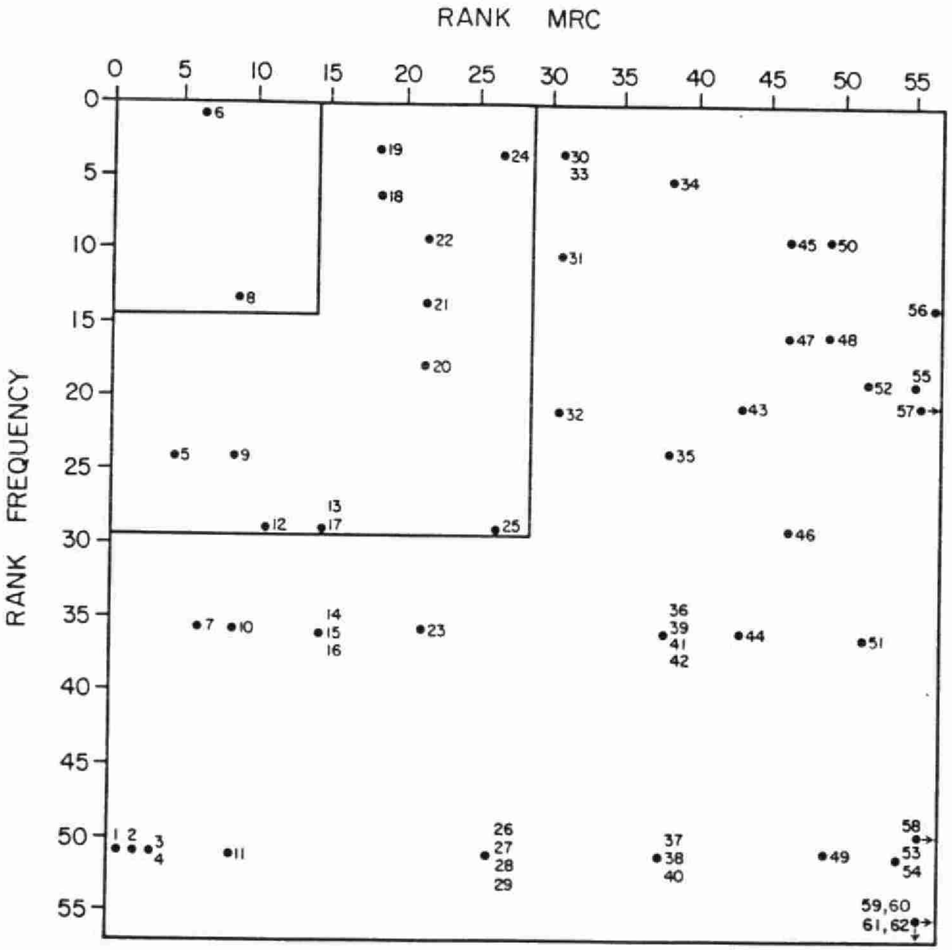
Division of Figure 6 into quadrants allowed association of relative importance for compounds depending on their location in this grid. The ranking plot was arbitrarily divided in half with the resulting quadrants being divided in half again for both axes. This provided a total of 16 potential grid areas that could be occupied by any one contaminant.

The quadrant with the highest rank for both categories (MRC and frequency of occurrence) would contain the most important compounds. The probability of compounds falling into this area by chance alone is very small (p=0.06). Di-octyl-phthalate and dichlorobenzene, both EPA priority pollutants, were located in this high priority quadrant and represented 1% of all compounds identified in this study.

The next larger division would contain those compounds falling into the highest priority area as well as those now falling into this quadrant (Figure 6). The probability of compounds falling into this quadrant by chance alone is greater than that of falling in the area previously discussed (p=0.25). Twelve compounds, six of which were EPA priority pollutants, were located in this second highest priority quadrant and represented about 4% of all compounds identified. The major compounds or groups of compounds identified in this area were chlorinated ethylenes (di and tetra), phenol, chloroform, 1,1,1-trichloroethane, xylene, hexane and the artifact methylene chloride.

Cholesta-3,5-diene and cholest-3-ene were located in the second priority quadrant but represent degradation products of cholesterol and are not recognized as hazardous contaminants. Carbon disulfide was also found in this quadrant and is recognized as a chemical manufacturing reagent but is present at concentrations below that considered toxic to activated sludge and therefore would be degraded. Dimethyl sulfide again in the same area is more representative of an industrial by-product and also is degradable at the concentrations present.

FIGURE 6: RANKING OF COMPOUNDS WHICH WERE FOUND MORE THAN ONCE AT 1 μg/L OR GREATER AND/OR AN EPA PRIORITY POLLUTANT WITH RESPECT TO FREQUENCY AND MEAN RANK CONCENTRATION (MRC).



1. Benzoic acid
2. 1,1-Biphenyl-2-ol
3. Isobenzofuranone
4. 2-Ethyl hexanol
5. 1,1-Dichloroethylene *
6. Di-n-octyl phthalate *
7. Acetone @
8. Dichlorobenzene *
9. Carbon disulfide
10. α,α -4-Trimethyl(s)-3-cyclohexene-1-methanol
11. 3-(1-Methyl-1,2-pyrrolidinyl) pyridine
12. Dimethyldisulfide
13. Xylene
14. 1,2-Dichloroethane *
15. 1,2-Dichloropropane *
16. Cresols *
17. Cholest-3-ene
18. Chloroform *
19. Tetrachloroethylene *
20 Cholesta-3,5-diene
21. 1,1,1-Trichloroethane *
22. Methylene chloride * @
23. Cholestan-3-ol acetate
24. Phenol *
25. Hexane
26. Cholestan-3-ol
27. p-Nonyl phenol
28. 1,1,2-Trichloroethane *
29. Tetrahydro-1-naphthonitrile
30. Benzene *
31. Methyl esters
32. Dimethyl ether
33. Trichloroethylene *
34. Toluene *
35. Methylene propane-dinitrile
36. Pyrene *
37. Trichlorofluoromethane *
38. Isopropanol
39. Phenanthrene/Anthracene *
40. Di-isopropylether
41. Fluoranthene *
42. 1,1-Dichloroethane *
43. Trimethyldodecatrienol @
44. Sub. Naphthalenes
45. Misc. Phthalates
46. Diethyl phthalate *
47. Trimethyltridecatrienenitrile @
48. Ethyl benzene *
49. Chlorobenzene *
50. p-Octyl phenol
51. Chlorodibromomethane *
52. Sub. Benzenes
53. 2- Methylbenzothiazole
54. Cholest-ene-diol
55. Nitrobenzene *
56. Dichlorobromomethane *
57. Di-n-butyl phthalate *
58. Hexachlorobenzene *
59. Carbon tetrachloride *
60. Dimethyl phthalate *
61. Pentachlorophenol *
62. Nitrophenol *

* -EPA priority pollutant
§ -Artifact

Compounds located in the remaining areas of the ranking plot should receive lower priority in abatement or follow-up programs than those identified above until additional information comes to light that would indicate the need to give them higher priority. Exceptions might include EPA priority pollutants which are located close to the second priority quadrant such as benzene, toluene, 1,2-dichloroethane and trichloroethylene.

The cross referencing exercise presented in Figure 6 focuses on compounds selected for their relatively high MRC and frequency of occurrence. This selection process facilitates the next stage of assessment which highlights compounds according to their effects on biota.

BIOLOGICAL SIGNIFICANCE

a) Fish Collections

The presence of organics in fish collected adjacent to the Toronto Main and Cornwall plants (Table 4) only indicates that sewage treatment plants can contribute to the organic chemical body burden of local fish. It is impossible to determine from fish sample data that fish collected adjacent to the two plants were being contaminated from sources (diffuse, direct, indirect) other than from the sewage treatment facilities.

b) Persistence

Biological accumulation of organics in fish, however, is used to determine the presence of compounds in water. Organic accumulation occurs either through the food chain (biomagnification) or through direct uptake from water (bioconcentration) or a combination of both (M.O.E.,1981).

Some organics occurred both in sewage treatment plant effluents and fish samples (Table 4). The relationship between organic concentration in effluent and fish is impossible to determine from this study due to the difference in the time period between collection of effluent and fish samples. Additionally, the fish sample analyses were limited to volatile organics. Also, non-point sources discharging into the local receiving waters were not taken into consideration.

However, laboratory experiments have developed relationships between bioaccumulation and the partition coefficient of compounds in order to estimate uptake of organic compounds by aquatic organisms, predominantly fish. The partition coefficient of a compound is the ratio of partitioning of an organic compound between a water and octanol system (Veith et al,1979; Leo et al,1971).

The log of the partition coefficients (log P) used in this study were obtained from tables presented in Leo et al (1971), Leo (1975); Veith et al (1979); Yalkow and Valvani (1980). Biological concentration factors (BCF), the degree to which compounds accumulate in fish compared to the water concentration, were calculated according to Veith et al (1979) as log BCF=0.85 (log P) - 0.70. The use of the log P in the preceding relationship provides an estimation of the bioconcentration factor of organic chemicals to within 60% of their actual value (Veith et al, 1979)

Biological concentration factors (BCF) for 26 of the compounds identified in this study are presented in Table 5. BCF values (Table 5) have been placed in perspective, by including a few familiar compounds (not identified in this study) such as DDT, PCBs, mirex, lindane and atrazine.

Since fish sample analysis was restricted to volatile organics, dichlorobenzene (Table 4) appeared as the compound with the highest BCF identified in fish tissue while non-volatile compounds with higher BCF values (eg. hexachlorobenzene, phenanthrene) were not measured in fish due to the method of analysis.

Calculation of BCFs for compounds identified in effluents indicates that most compounds would be of low persistence with estimated clearance half lives in fish (t 1/2) of less than 100 hours. The estimate of clearance (t 1/2) for lindane is about 267 hours, according to the relationship developed by Neely (1979) using molecular weight, solubility and vapour pressure.

$$\text{Log } t(1/2) = 0.0027(1/H) - 0.282 \times \log S + 1.08$$

$$\text{where: } H = \frac{\text{vapour pressure x molec. weight}}{\text{solubility (mg/l)}}$$

units:(mm Hg m3/mole)

$$S = \frac{\text{solubility (mg/l)}}{\text{molec. weight}}$$

units:(mM/liter)

All compounds listed below lindane in Table 5 have a t1/2 less than the 100 hour criteria (EPA, 1972). In fact, the half life for chlorobenzene is 8 hours. However, constant input into receiving waters would result in continual body burden of organics in local biota despite the short half life or clearance rates of the more common compounds identified. Compounds with BCFs greater than that of lindane were considered environmentally significant due to their degree of persistence.

c) Sublethal Toxicity

Another measure of biological activity frequently used is the LC50 (concentration lethal to 50% of the population). The LC50 values (Table 5) were calculated according to Smith and Craig (1983) from the formula Log LC50mM/1=1.08 - 0.88 x (Log P) where mM=milli moles.

Estimation of the threshold no-effect concentration for the protection of biota for non persistent compounds (t 1/2 < 100hrs) is 0.1 times the estimated LC50 value. For those compounds considered persistent (t 1/2 > 100 hours) .01 times the LC50 value is the no effect level estimate. These conventional application factors are used when insufficient sublethal data are available for compounds under consideration (EPA, 1972). Estimated threshold sublethal concentrations for selected compounds identified in effluents appear in Table 5. Compounds with "no effect" concentrations greater than 0.1, 1, 10 and 100 ug/1 would conceivably produce a sublethal biological effect (reproductive and growth impairment) at the concentration ranges A, B, C and D respectively, assuming no dilution of the effluent.

Comparison of the estimated threshold effect concentration ranges with measured concentration ranges in effluents (Table 1) for compounds listed in Table 5 indicate that only hexachlorobenzene, phenanthrene, diphenyl ether and biphenyl appeared at concentrations above those estimated to produce sublethal effects in fish. These compounds were also considered persistent in addition to existing at sublethal concentrations.

In conclusion:

1. Compounds discharged from STP plants could affect the quality of local receiving waters and local forage and sport fish residing near the source. What is not evident through this study is the identification of specific sublethal fish responses. Also, compounds identified in the fish samples may have been introduced to the sampling sites from sources other than the STP discharges.

2. Hexachlorobenzene, phenanthrene, pentachlorophenol, diphenyl ether and biphenyl were identified as persistent and, with the exception of pentachlorophenol, occurred at concentrations above the estimated sublethal threshold.

Table 5: Log partition coefficients; Log bioconcentration factors and no effect concentration 0.1 x LC50 of some selected organic compounds found in this study including marker compounds.

COMPOUND	Log P.	Log BCF	No Effect Level(ug/1) (0.1xLC50 ug/1)(5)
DDT(1)(Marker only)*	6.19	4.56	
PCB(1)(Marker only)*	5.90	4.32	
Hexachlorobenzene(1)	5.85	4.27	** 0.24 @
Mirex(1)(Marker only)*	5.83	4.26	
Phenanthrene(1)	4.85	3.42	** 1.16 @
Pentachlorophenol(2)	4.51	3.13	** 3.44
Diphenyl ether(3)	4.08	2.77	** 5.25 @
Biphenyl(3)	4.04	2.74	** 5.27 @
Lindane(1)(Marker only)*	3.96	2.67	
Chlorobenzene(1)	3.94	2.65	46.20
Dichlorobenzene(4)	3.37	2.16	191.00
Styrene(3)	3.16	1.99	100.00
Ethyl benzene(4)	3.15	1.98	212.32
Hexane(2)	3.10	1.94	190.00
Xylene(2)	3.04	1.88	265.30
Carbon tetrachloride(2)	2.64	1.54	876.00
Tetrachloroethylene(2)	2.48	1.41	1310.00
Toluene(2)	2.47	1.40	737.00
1,1,1-Trichloroethane(3)	2.47	1.40	1051.20
Ethyl phenol(2)	2.40	1.34	987.28
Benzene(2)	2.20	1.17	1282.00
Indole(2)	2.13	1.11	1885.90
Trichloroethylene(2)	2.11	1.09	2202.70
Chloroform(2)	1.97	0.97	2650.40
Atrazine(1)(Marker only)*	1.88	0.90	
Nitrobenzene(3)	1.83	0.86	3631.70
1,1-Dichloroethylene(2)	1.74	0.78	3432.00
Phenol(2)	1.50	0.58	5411.30
1,2-Dichloroethane(3)	1.45	0.53	6303.70
Ethanol(2)	0.32	-0.43	28978.00
Acetone(2)	-0.24	-0.93	113546.40

(1)-Veith et al, (1979)
(2)-Leo et al, (1971)
(3)-Leo, (1975)
(4)-Yalkowsky and Valvani, (1980)
(5)-Smith and Craig, (1982)
*-Marker compounds only, these compounds not found in this study.
**-No-effect level for persistent compounds estimated as 0.01 of the LC50 (for fish reproductive and growth impairment only)
@-Compounds that occurred in effluents above sublethal "no effect concentration level

INTERPRETATION AND EVALUATION OF SELECTION CRITERIA

The previous sections of this report have selectively isolated compounds from Table 1 according to specific yet different criteria. Compounds were first selected according to their concentration (MRC), their frequency of occurrence and later highlighted where persistent or sublethal activity was anticipated. A summary of these selection and evaluation exercises appear in Table 6 which has been separated into five groups each containing compounds with common attributes.

A brief review and assessment of the compounds occuring in each group follows.

A) GROUP I

The first group of compounds (Table 6) occurred in lower frequency and concentration (probably due to their low water solubility), consequently they were not identified in the top 1% or 5% of compounds in this study (Table 1). However, these compounds were recognized as persistent and three (hexachlorobenzene, phenanthrene, and pentachlorophenol) are EPA priority pollutants.

These compounds, with the exception of pentachlorophenol, were also measured in concentrations estimated to produce sublethal effects in fish within the mixing zone of the effluent. Phenanthrene, a polynuclear aromatic, is metabolized by fish and therefore will not accumulate but may result in the production of mutagenic precursors in fish (IJC, 1983). Phenanthrene has been detected in Great Lakes sediment, carp and pike from Hamilton harbour and Detroit River and herring gulls from Kingston which indicates active inputs.

The remaining two compounds in this group (diphenyl ether and biphenyl) are comparable to lindane in persistence but are not routinely analyzed in fish contaminants surveys.

Pentachlorophenol has been reported by other authors (Jones, 1981; Fox, 1978) as occurring in watersheds along Lakes Erie, Ontario and Superior shorelines, previously sampled sewage treatment plant effluents and in receiving waters adjacent to pulp and paper discharges and wood preserving operations.

Hexachlorobenzene has been measured in Great Lakes sediment samples (Oliver and Nicol, 1982), in fish from Lake Ontario (Norstrom et al, 1978; Niimi, 1979; Gilbertson, 1978) Lake Superior (Swain, 1978) and in aquatic birds (Matheson et al, 1980; Norstrom, 1978; Mineau, 1982; Holden, 1973).

B) GROUP II

The second group of chemicals represented the top 1% of compounds identified in this study with respect to frequency of occurrence and concentration and are all recognized as EPA priority pollutants. The half lives (t1/2) of these compounds were calculated to be less than 100 hours, indicating their limited biological persistence.

Table 6: Summary Of Compounds Highlighted For Pesistent and Sublethal Characteristics (Table 5), Frequency-Concentration Correlation (Figure 6) And Identification As An EPA Priority Pollutant

Compound	Persistent (t1/2>100hrs) Table 5	>sub-lethal threshold Table 5	Top 1% Freq/Conc Fig. 6	Top 5% Freq/Conc Fig. 6	EPA	Group
Hexachlorobenzene	x	x			x	I
Phenanthrene/Anthracene	x	x			x	
Pentachlorophenol	x				x	
Diphenyl ether	x	x				
Biphenyl	x	x				
Dichlorobenzene			x	x	x	II
Di-octyl-phthalate			x	x	x	
Chloroform				x	x	III
1,1,1-Trichloroethane				x	x	
1,1-Dichloroethane				x	x	
Tetrachloroethylene				x	x	
Phenol				x	x	
Xylene				x	x	
Benzene				o	x	IV
Toluene				o	x	
Chlorobenzene					x	
Ethyl benzene					x	
Nitrobenzene					x	
Trichloroethylene				o	x	
Carbon tetrachloride					x	
Chlorodibromomethane					x	
Dichlorobromomethane					x	
Trichlorofluoromethane					x	
1,1-Dichloroethane					x	
1,2-Dichloroethane				o	x	
1,1,2-Trichloroethane					x	
1,2-Dichloropropane					x	
Nitrophenol					x	
Fluoranthene					x	
Pyrene					x	
Dibutylphthalate					x	
Carbon disulfide				x		V
Dimethyl disulfide				x		
Hexane				x		

o - close to top 5% quadrant

C) GROUP III

Compounds in the third group represented the second highest frequency-concentration group of organic chemicals (top 5%) and have all been identified as EPA priority pollutants. Compounds of note include 1,1-dichloroethylene, tetrachloroethylene and chloroform which are suspected carcinogens (EPA, 1979).

D) GROUP IV

Compounds in the fourth group occurred with lower frequencies (top 23%) and concentrations. All compounds in this group were highlighted solely because of their identification as EPA priority pollutants. That is, these compounds occurred only once or if more than once, at trace levels (less than or equal to 1.0 ug/l). The important compounds in this group are chloroethanes (1,2 and 1,1,2) and carbon tetrachloride which are potential carcinogens (U.S. EPA, 1979; IJC, 1983). Benzene, toluene, 1,2-dichloroethane and trichloroethylene bordered close to the group III compounds (fig. 6) and therefore deserve additional attention.

E) GROUP V

The final group of compounds were isolated solely on the strength of their high frequency of occurrence and concentrations (top 5 %). The sulfides can be biologically degraded. None of these compounds are chlorinated as are most of the aliphatics of Group IV. Therefore this group would not likely represent an environmentally significant collection of compounds.

F) SUMMARY

Compounds selected for inclusion in monitoring, surveillance and abatement programs are summarized in Table 7 according to rationales identified in the above discussion of each group.

Table 7: Compounds, with accompanying rationale, requiring emphasis in contaminants monitoring, surveillance and abatement programs

GROUP	COMPOUNDS SELECTED	RATIONAL
I	Hexachlorobenzene	
	Pentachlorophenol	
	Diphenyl ether	-Persistent Contaminants
	Biphenyl	
	Phenanthrene/Anthracene	-PAH (EPA-Priority Pollutant)
II	Dichlorobenzene	- highest release levels
	Di-octyl-phthalate	- & EPA Priority Pollutants
III	Chloroform	
	1,1,1-Trichloroethane	- very high release levels
	1,1-Dichloroethylene	- &
	Tetrachloroethylene	- EPA Priority Pollutants
	Phenol	- very high release levels
	Xylene	
IV	Benzene	
	Toluene	- high release levels
	Trichloroethylene	& EPA-Priority Pollutants
	1,2-Dichloroethane	
	Carbon tetrachloride	- EPA Priority Pollutant
V	none	-not environmentally significant
TOTAL	19 compounds	

SIGNIFICANCE OF ORGANICS DISCHARGED FROM SEWAGE TREATMENT PLANTS

COMPARISON WITH INDUSTRIAL DISCHARGES

In order to place the release of the 19 high priority compounds in perspective with those from the chemical manufacturing industries a table of concentration range % occurrence was prepared (Table 8).

The industrial effluent data were generated from a 1979 St. Clair River survey using grab sample collection at 17 final discharges. The concentration ranges for the industrial dischargers were extended taking into account the following additional ranges: 100 - 1000 ug/l (D), 1 - 10 mg/l (E) and 10 - 100 mg/l (F). The industrial effluents included in this overview are Imperial Oil, ESSO Chemical, Polysar, Dow, Sun Oil, Shell Oil, Ethyl Corporation, Petrosar, Dupont and CIL. Although the discharges from the above industries were analyzed for US EPA priority pollutants, only those identified in this report are compared while more detailed industrial information appears in another report (Munro et al, in preparation).Treatment of process waters in the refinery and chemical manufacturing sectors varies and often tends to be specific for removal of wastes from upstream operations. Oil separation, extended aeration, biological treatment and charcoal filtration are often used in different combinations to provide effluent treatment.

Data in Table 8 were combined to represent total chemical releases for sewage treatment plants and industries according to the proportion of samples found to contain specific concentrations of each compound. While percentage occurrence values range considerably for each compound and different concentrations it is clear that most compounds occur in the A to C range regardless of sources. Focus on occurrences greater than 10% provides a crude comparison of concentration clustering which provides a comparable chemical profile for both sources.

Although this means of comparison is limited by the differences between the studies it is possible to deduce that release rates of the 19 contaminants from sewage treatment plants prioritized in this study appear to be similar to those from chemical manufacturing sources in the St. Clair River.

Comparison of total % occurrence for each compound indicates that, for 8 of the 13 compounds common to both sources, the frequency of chemical observation was greater in sewage treatment plants than industry. This is perhaps not surprising as these compounds were selected from sewage treatment plant chemical profiles and therefore should be more representative of sewage treatment plants. However, this does not detract from the exercise that serves to compare contaminant losses.

Visual comparison of the losses of the 19 high priority sewage treatment plant contaminants with losses of the same compounds from industrial sources indicates that releases are of equivalent significance.

TABLE 8: Comparison of Concentration Ranges For 19 High Priority Compounds From Sewage Treatment Plants And for Industrial Sources

COMPOUND	STP's SAMPLES N	STP's TOTAL% FREQ.	STP's % OCCURRENCE A	B	C	D	TOTAL % COMPARISON		INDUSTRIAL EFFLUENTS SAMPLES N	TOTAL % FREQ.	INDUSTRIAL EFFLUENTS % OCCURRENCE A	B	C	D	E	F
Hexachlorobenzene	18	5	6	0	0	0		*	59	24	8	8	8	0	0	0
Pentachlorophenol	18	5	5	0	0	0		*	59	15	3	7	5	0	0	0
Diphenyl ether	18	5	0	5	0	0				------						
Biphenyl	18	17	11	6	0	0				------						
Phenanthrene/ Anthracene	18	17	6	11	0	0			59	39	19	15	5	0	0	0
Dichlorobenzene	14	64	7	50	7	0	*		59	2	2	0	0	0	0	0
Di-octyl phthalate	18	100	6	61	33	0	*			------						
Chloroform	14	100	0	100	0	0	*		59	53	15	29	7	2	0	0
1,1,1-Trichloroethane	14	64	29	29	7	0	*		59	19	7	5	7	0	0	0
1,1-Dichloroethylene	14	36	0	21	7	7	*		59	19	5	12	2	0	0	0
Tetrachloroethylene	14	100	50	36	14	0	*		59	78	34	34	7	3	0	0
Phenol	18	78	22	39	17	0	*		59	20	7	8	5	0	0	0
Xylene	28	29	0	7	21	0				------						
Benzene	14	100	79	0	21	0	*		59	76	25	15	20	12	2	2
Toluene	14	92	50	43	0	0	*		59	75	42	24	7	2	0	0
Trichloroetylene	14	100	57	43	0	0		*	59	72	47	19	3	3	0	0
1,2-Dichloroethane	14	21	21	0	0	0		*	59	78	34	20	24	7	2	0
Carbon tetrachloride	14	7	7	0	0	0			59	------						
AVERAGE		52	19	25	7	0	TOTAL 8	5		44	19	15	8	2	.3	0

Comparison of data in this study with that of an EPA sewage treatment plant survey for organic compounds (EPA, 1982) indicated similar results to those reported here. Although more samples were analyzed from 50 plants (about 300) in the EPA study, the analyses were limited to priority pollutants. All 19 of the priority compounds highlighted in this study were identified in the EPA survey. While the EPA reported average concentrations of priority pollutants detected in each of the 50 plants surveyed, there appeared to be relatively good agreement with the data presented in figure 6 considering a number of other compounds were interspersed among the same EPA priority pollutants.

COMPARISON WITH EXISTING WATER QUALITY CRITERIA

Water quality criteria have been developed by different agencies for most of the nineteen compounds highlighted in this study. Comparison of the concentrations of compounds observed in STP effluents with respective water quality criteria is presented in Table 9. Where the upper end of the concentration range for any compound exceeded the MOE, EPA or WHO objectives or guidelines for surface or drinking waters that compound has been identified.

Dichloroethylene exceeded the WHO drinking water guideline on five occasions (35% frequency) at four plants. Guidelines were exceeded by factors of ten in three samples and by 100 and 1000 fold in two other samples.

Tetrachloroethylene exceeded the WHO drinking water tentative guideline on two occasions (14% frequency) by a factor of ten; once at each of two different plants.

Benzene exceeded the WHO drinking water guideline by a factor of ten on three occasions (21% frequency); once at each of three different plants.

Xylene exceeded the EPA criteria for biota by a factor of ten on four occasions (100% frequency) at three different plants.

Dichlorobenzene exceeded the MOE proposed criteria for biota on eight occasions (89% frequency) at five plants. Criteria were exceeded by a factor of ten on all occasions but one which was exceeded by a factor of 1000.

Hexachlorobenzene exceeded the MOE proposed criteria for biota by a factor of 100 at the one plant where it was identified.

Phenol exceeded the MOE criteria for fish tainting and drinking water taste and odour limits on ten occasions (71% frequency) at 6 plants; levels exceeded criteria in both cases by a factor of ten and 100 on seven and three occasions respectively.

Pentachlorophenol was identified only once and exceeded the MOE proposed criteria for biota by a factor of ten.

Di-octyl-phthalate exceeded the MOE objective for biota at all plants on all eighteen occasions.

Indication that the above compounds exceeded various objectives provides additional support for the need to monitor, assess and develop abatement strategies for the release of those compounds.

It is important to appreciate however, that the samples analysed were collected at the end of STP discharge pipes. The concentrations reported in this study do not represent those at the edge of respective mixing zones where MOE water quality objectives are to be met. The scope of work in this study did not include the delineation of mixing zones nor was it identified that concentrations of organics would be estimated in surface waters or drinking water sources outside the mixing zone. However, accumulated drinking water data from selected municipalities, eg Metropolitan Toronto, have not shown concentrations of chemicals which have been judged by public health authoritites to be of immediate concern to human health.

SUMMARY

This study was designed to inventory, semi-quantitatively, organic compounds (with the exception of pesticides and PCB's) discharged by sewage treatment plants. The compounds identified were to be evaluated according to frequency-concentration patterns, structure-activity relationships and their presence on the EPA priority pollutant list.

While this report adds to the understanding of organics entering the Great Lakes and provides direction for future program planning it does not reflect ambient water quality or drinking water quality conditions. Extrapolation of this data to estimate concentrations of organics inside or outside the mixing zones of respective STP's or any impact on raw drinking water sources and treated drinking water quality, must be recognized as speculative.

As a result of the above exercise nineteen compounds were highlighted for inclusion in abatement programs and for future treatment and hazard assessment program development. Numerous programs are currently underway in the Ontario Ministry of Environment and Environment Canada which address many of these needs.

TABLE 9: Comparison of Concentrations of Nineteen Compounds with Existing Provincial and International Water Quality Criteria.

COMPOUND (ug/L)	Highest Conc in Study #	AQUATIC LIFE MOE	AQUATIC LIFE EPA	DRINKING WATER MOE	DRINKING WATER EPA	DRINKING WATER WHO	Exceeded
Total trihalomethanes	10	–	1240	350	100		
Chloroform	10	–	1240	–	–	30 a	
1,2-Dichloroethane	10	–	20000	–	–	10 a	
1,1,1-Trichloroethane	100	–	–	–	–	–	
1,1-Dichloroethylene	>100	–	11600 ac	–	–	0.3a	*
Trichloroethylene	10	–	45000 ch	–	–	30 a T	
Tetrachloroethylene	100	–	840 ch	–	–	10 a T	*
Benzene	100	–	5300 ac	–	–	10 a	*
Toluene	10	–	17500 ac	–	340	–	
Xylene	100	–	50	–	620	–	*
Dichlorobenzene	100	2.5-4 @	763 ch	–	–	0.1-3.0 b	*
Hexachlorobenzene	1	0.0065 @	50 ac	–	–	0.01 a	*
Biphenyl	10	–	–	–	–	–	
Phenanthrene/ Anthracene	10	–	–	–	–	–	
Diphenyl ether	10	–	–	–	–	–	
Phenol	100	1 +	2560 ch	2 b	–	–	*
Pentachlorophenol	1	0.5 @	3.2 ch	–	–	10	*
Carbon tetrachloride	1	–	35200 ac	–	500	3 a T	
Di-octyl-phthalate	100	0.2	3 ch	–	–	–	*

a – These guideline values were computed from a conservative hypothetical mathematical model which cannot be experimentally verified. Uncertainties involved may amount to two orders of magnitude (ie. from 1/10 to 10 times the number).

b – not health related but may be detectable by taste and odour .

T – when available carcinogenicity data could not support a guideline value but the compounds were judged to be of importance in drinking water and guidance was considered essential a tentative guideline was set on the basis of available health related data.

ac – acute toxicity to aquatic biota expected; no chronic toxicity data available.

ch – chronic toxicity to aquatic biota expected.

+ – 1 ug/L is a total phenols number recommended to protect against tainting of edible fish-flesh.

@ – Ontario Ministry of Environment proposed objective.

* – indicates that any one of the water quality guidelines have been exceeded

– concentration values represent the upper end of the observed concentration range at the end of the pipe and do not reflect ambient or drinking water concentrations.

RESEARCH NEEDS

1. There is a recognized need to continue studies to determine the removal efficiency of classes of organics according to the levels of treatment such as those underway within the Ministry and at the CCIW Wastewater Treatment Centre.

2. There is a need to characterize the impact of organic losses from STPs on biological material and sediments in receiving waters through hazard assessment and trend analysis programs.

3. There is a need to expand the base of routinely analyzed chemicals in environmental samples (air, water, solids). Special emphasis should be placed on developing the capability of analysing solvent extractable compounds in biological material.

4. There is a need for further evaluation to be completed on compounds highlighted in this report with respect to controlling losses at the source or through treatment and to determine the environmental fate of those chemicals.

5. There is a need to continue development of chemical profiles of treated sewage sludges since low solubility compounds found in sewage treatment plant effluents have a high affinity for particulate organic matter.

6. There is a need to investigate air quality for the presence of volatile organics around sewage treatment plant settling ponds, sludge incinerators and other waste treatment areas.

7. There is need to increase public awareness concerning their role in contributing to the organic chemical loading to the Great Lakes through their activities at home and at their place of work.

RECOMMENDATIONS

1. Research needs identified in this study should continue to be addressed though internal and external program development and promotion.

2. Due to the ability of fish to bioconcentrate organic compounds, nearshore and sport fish surveillance programs should include analysis of persistent compounds to determine the significance and range of distribution of Group I chemicals and to determine the localized impact of less persistent Group II and III chemicals.

3. The following 19 chemicals should be emphasized in surveillance, monitoring and abatement programs.

Chloroform	Dichlorobenzene
1,2-Dichloroethane	Hexachlorobenzene
1,1,1-Trichloroethane	Biphenyl
1,1-Dichloroethylene	Phenanthrene/Anthracene
Trichloroethylene	Diphenyl ether
Tetrachloroethylene	Phenol
Benzene	Pentachlorophenol
Toluene	Carbon tetrachloride
Xylene	Di octyl phthalate

PROGRAMS UNDERWAY IN 1984

The following programs have been initiated by the Ontario Ministry of Environment and Environment Canada since this survey of organics in STP's began in 1979.The variety and scope of the programs indicate the interest and concern both agencies have in the monitoring and treatment of domestic and industrial wastes. Further details of these studies may be obtained from the responsible operational groups in the respective agencies.

1. Fate of Trace Organics in Biological Treatment Systems. Biological Processes Section, Wastewater Technology Centre, Environment Canada, EPS.
An evaluation of the effectiveness of activated sludge systems to remove trace contaminants by volatilization, sludge adsorption or biological oxidation.

2. Removal of Polynuclear Aromatic Hydrocarbons (PAH) from Industrial Wastewater. Biological Process Section, Wastewater Technology Centre, Environment Canada, EPS.
An evaluation of PAH removal processes from coke waste, coal liquifaction and oil sands upgrading.

3.Monitoring the Fate of Selected Polynuclear Aromatics Through a Municipal Wastewater Treatment Plant. Environmental Technology Section, Laboratory Services and Applied Research Branch, Ontario Ministry of Evironment.

4. Pilot Plant Study of Removal of Trace Organics in Niagara River Water. Environmental Technology Section, Laboratory Services and Applied Research Branch, Ontario Ministry of Environment.

5. Development of the HAZPRED Model: Phase I. Enviromental Technology Section, Laboratory Services and Applied Research Branch, Ontario Ministry of Environment.
Development of a computerized model to predict the incidence of trace organic contaminants in raw sewage based on land use characteristics and type of industry in the municipality.

6. Toxics Identification and Mobility in Sludges. Residue Management Section, Wastewater Technology Centre, Environment Canada, EPS.
Development of a data base of toxics in residues and leachates of sewage sludges. Mathematical models will be developed for application in landfill operations to estimate infusion rates into aquifers.

7. Biological Monitoring of Receiving Water Quality. Water Resources Branch and Laboratory Services and Applied Research Branch, Ontario Ministry of Environment.
Analysis of newly identified compounds is being incorporated into existing sport and nearshore fish contaminant monitoring programs and sediment and benthic surveys.

8. A Revised Monitoring Scheme for Persistent and Toxic Organics in Great Lakes Sport Fish. Trace Organics Analysis Section, Laboratory Services and Applied Research Branch, Ontario Ministry of Environment.
An evaluation, by GC/MS, of extractable organics in sport fish from selected sites in the Great Lakes will be completed. An increased range of organics present in different geographical locations will be identified. Additional parameters to be included in routine monitoring will be recommended and revisions to current analytical methods will be instituted.

9. The Effect of Sludge Conditioning/Processing on Toxics Fate/Mobility. Residue Management Section, Wastewater Technology Centre, Environment Canada, EPS.

An assessment of the effect of anaerobic digestion, heat treatment and polymer conditioning on toxics fate and mobility will be completed.

10. Fate of Trace Organics in Sludge Applied to Land. Residue Management Section, Wastewater Technology Centre, Environment Canada, EPS.

The fate of polynuclear aromatic hydrocarbons in sludge soil applications will be determined.

11. Cost Effective Toxics Control via Incineration. Residue Management Section, Wastewater Technology Centre, Environment Canada, EPS.

The thermal stability of toxic compounds will be determined.

12. Characterization of Trace Organic Contaminants in Storm Water Runoff. Environmental Hydraulics Division, National Water Research Institute, Canada Centre for Inland Waters, Environment Canada.

Analysis of stormwater in selected municipalities for metals, conventional parameters and EPA priority pollutants were completed.

13. Drinking Water Assessment Program. Environmental Technology Section, Laboratory Services and Applied Research Branch, Ontario Ministry of Environment.

A data base of 110 water quality parameters measured in treated and distributed waters at four locations within 35 municipalities will be established.

14. Provincial Water Quality Objectives. Water and Wastewater Management Section. Water Resources Branch, Ontario Ministry of Environment.

Draft water quality criteria have been prepared for homologues of the chlorinated phenols and important isomers of chlorinated benzenes.

Chlorinated ethanes and chlorinated ethylenes have been recommended for provincial water quality objective development. (Working Group I, Water Management Steering Committee).

15. Toxics Imobilization in Sludge by Solidification. Residue Management Section, Wastewater Technology Centre, Environment Canada, EPS.

Fundamental studies to determine the mechanisms of solidification and the development of mathematical models to assess contaminant leachability from solidified wastes will be completed.

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APPENDIX I

SEWAGE TREATMENT PLANTS CHOSEN FOR THE 1979 S.T.P. STUDY

STP	Treatment Type	Flow (m3/day) x 1000	Capacity (m3/day) x 1000	Receiving Water
Toronto (Main)	Conventional Secondary Phosphorous Removal	725.81	910.00	Lake Ontario
Burlington	Extended aeration Phosphorous Removal	62.16	93.28	Hamilton Harbour
Hamilton	Conventional Secondary Phosphorous Removal without chemicals	265.39	273.00	Hamilton Harbour
Stratford	Conventional Secondary Effluent Polishing Phosphorous Removal	16.78	27.30	Avon River
Kitchener	Conventional Secondary Phosphorous Removal	54.47	122.85	Grand River
Lakeview (Mississauga)	Conventional Secondary Phosphorous Removal	159.22	227.50	Lake Ontario
Cornwall	Primary Phosphorous Removal	49.00	37.54	St. Lawrence River
Goderich	Conventional Secondary	6.57	4.55	Lake Huron
Sarnia (city)	Primary	38.28	65.98	St. Clair River

APPENDIX II

CORNWALL

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity	Total P
Aug 10/79	105	75	10	.03	0.1	198	30	2.3	-	-
Aug 13/79	115	80	11	.03	0.1	220	40	3.0	-	-
Aug 16/79	130	145	7.8	.01	0.1	298	45	2.9	-	-
Nov 14/79	135	116	5.8	.03	.67	218	50	1.2	32	1.9
Nov 18/79	110	81	7.2	.14	< .10	282	110	1.6	57	3.4
Nov 21/79	125	104	9.3	.05	.15	248	110	2.8	42	5.2
Dec 10/79	116	78	7.4	.08	0.1	234	100	2.4	55	4.1
Dec 13/79	80	58	4.8	.15	0.5	276	50	1.7	36	2.4
Dec 16/79	90	58	7.6	.06	0.2	277	65	2.0	32	3.5

GODERICH

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity
Aug 23/79	3.0	8.0	11.0	.56	4.7	192	5	0.2	5.1
Aug 26/79	2.5	12.0	12.0	.36	2.1	204	6	0.1	5.1
Aug 29/79	2.5	9.0	14.0	.57	1.9	208	13	0.2	6.4
Oct 24/79	7	22	7.6	.49	2.0	204	30	0.2	14
Oct 28/79	16	32	10	.62	1.6	238	25	0.3	15
Oct 31/79	7	16	10	.92	2.3	240	20	0.3	9.9
Dec 1/79	3.0	13	3.6	.29	5.0	269	20	0.1	4.3
Dec 4/79	3.0	9	4.8	.58	4.8	275	10	0.1	4.0
Dec 7/79	9.0	13	5.2	.64	5.0	255	10	0.1	8.6

SARNIA

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity
Aug 17/79	42	21	18	.01	.1	174	15	2.7	18
Aug 20/79	32	19	19	.01	.1	176	10	2.9	23
Aug 23/79	34	28	21	.01	.1	179	34	1.8	4
Oct 24/79	42	30	20	.02	.10	161	15	4.5	16
Oct 28/79	44	37	20	.01	.10	204	40	4.0	23
Oct 31/79	40	38	18	.01	.10	151	20	4.7	13

LAKEVIEW

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity
June 19/79	13	34	6.1	.36	3.7	162	10	0.6	6.3
June 22/79	15	26	3.3	1.7	6.0	127	12	0.2	3.6
June 25/79	E	18	2.5	1.8	10	106	11	< 0.1	-
Nov 1/79	8.0	27	11	3.1	.68	165	15	0.5	6.3
Nov 4/79	8.0	25	14	3.8	1.7	180	9	1.0	5.5
Nov 7/79	11	31	14	2.0	.56	186	10	0.5	4.7

E - Sample exhausted

HAMILTON

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity	Total P
Sept 13/79	1.4	11	17	.05	13	68	10	.3	3.2	-
Sept 19/79	5.0	15	14	.06	6.7	105	20	.2	11	-
Nov 22/79	58	23	16	.02	68	106	90	0.1	20	4.6
Nov 25/79	138	83	15	< .01	13	116	240	.01	84	38

KITCHENER

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity	Total P
Nov 22/79	5.0	16	7.6	.21	14	264	11	0.2	7.6	1.3
Nov 25/79	1.6	6.0	.20	.04	21	199	<5	0.1	5.0	.52
Nov 28/79	1.4	8.0	1.6	.48	17.0	249	<5	0.2	2.7	.72

TORONTO (MAIN)

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity	Total P
June 19/79	14	30	16	.15	2.0	185	11	0.1	7.7	-
June 22/79	17	47	16	.09	1.0	189	26	0.2	E	-
June 25/79	8.0	23	20	.12	.5	205	11	0.6	-	-
Nov 1/79	3.5	13	20	.74	.26	E	9	E	E	-
Nov 4/79	3.5	16	22	.65	.45	192	15	E	4.8	-
Nov 7/79	6.0	15	20	<.10	.21	196	10	0.2	6.5	-
Dec 9/79	6.0	13	19	.36	0.7	E	6	E	E	.78
Dec 12/79	9.0	14	19	.28	0.6	E	9	E	E	1.1

E - Sample exhausted

BURLINGTON

Date	BOD_5	TOC	Ammonia	Nitrite	Nitrate	Alk.	Total Susp. Solids	MBAS as LAS	Turbidity	Total P
Sept 13/79	3.0	11	1.2	.21	19.0	80	5.0	E	E	-
Sept 19/79	2.5	16	.4	.04	11	120	6.0	0.2	E	-

E - Sample exhausted

ANALYTICAL PROCEDURE

The following is an outline of the methodology for the analysis of effluent samples for extractable and volatile components and for the analysis of fish for volatiles only.

EXTRACTABLES

The first sampling series were initially extracted by hand using a sample volume of 800 ml. The extraction solvent used was methylene chloride at a pH of 2 and 11. On screening these samples by GC followed by GC/MS it was found that this method had inadequate sensitivity, so for these and all subsequent samples, a more sensitive technique was applied.

A 4L aliquot of each sample was extracted by a continuous liquid/liquid extraction procedure using benzene (250 ml) as the solvent. The extraction was carried out at a basic and acidic pH for 24 hours each. An internal standard (D10 Anthracene or D5 Nitrobenzene) was added to the solvent prior to evaporation to a small volume (100 ul) in order to facilitate quantification.

Analysis by GC/MS followed with the conditions outlined below.

GC/MS SYSTEM: Finnigan 4021; Incos data system.

GC SYSTEM:

Column; 6' x 1/8" i.d. glass; 1% SP2250 on Supelcoport 100/120 mesh.

Temperature: a) $60^{\circ}C$ hold 2 min.
b) to $250^{\circ}C$ at $10^{\circ}C/min$.
c) $250^{\circ}C$ hold 20 min.

Carrier Gas: Helium 30 ml/min.

Interface: Jet separator

MS SYSTEM:

Electron Multiplier: 1.0 Kv (conversion dynode-3.0 Kv)

Electron Energy: 66 ev

Mass Range: 45-500 a.m.u.

Ionization Mode: Electron impact

APPENDIX III

VOLATILES

a) Effluents

A 1L aliquot of each effluent was analyzed for volatile organics by the purge and trap technique followed by GC/MS. The appropriate internal standard was added to each effluent and the sample was purged at 80 to 90°C for 30 mins with a flow of nitrogen. The volatile components were trapped on a tenax trap (4" x 1/4" o.d.). The tenax trap was then desorbed at 200°C with a flow of helium onto the GC column and GC/MS analysis carried out. Quantification was carried out by comparing the data system response for specific ions for each component with the response for the internal standard (1,3-Dichlorobutane).

The following conditions were used.

GC SYSTEM:

Varian: 2740 with F.I.D.

Column: 12' x 1/8" i.d. Nikel 0.2% Carbowax 20M
on Carbopack c 60/80 mesh

Temperature: a) 35°C hold 6 min
b) 35°C to 170°C at 8°C/min.
c) 170°C hold

Carrier Gas: Helium 30 ml/min (via desorption unit)

FID:MS split- 4:1

MS

Dupont- 21-491 B

Data System: Kratos DS50S

Electron Energy: 70 ev

Approx. Mass Range: 28-420 a.m.u.

Scan Rate: 2 sec/decade

Ionization Mode: Electron Impact

b) Fish

1.5g of homogenized fish tissue was added to the purge vessel together with 500 ml pre-purged millipore water. The analysis was then carried out as described for the effluents.

APPENDIX IV

CURRENT SEWAGE TREATMENT

The following outlines the basic processes applied to sewage wastes according to level of treatment. More detailed information can be found in (MOE, 1980).

Primary Treatment

Influents are first strained to remove items capable of clogging pumps and pipes then aerated and passed into a primary settling tank to remove suspended solids. After clarification the effluent is chlorinated and discharged to the receiving waters. The sludge from the primary settling tank is moved to digesters for biological degradation.

Conventional Secondary Treatment

Conventional secondary treatment of effluent from the primary treatment stage is aerated by thorough mixing and aeration to promote decomposition through oxidation. A clear effluent is produced with up to 95% of the biological oxygen demand (BOD) and suspended solids (SS) removed.

Extended Aeration

Wastes entering the secondary phase of treatment are aerated immediately without primary settling. The extended aeration usually lasts 18-24 hours providing greater oxidation of wastes.

Tertiary Treatment

Tertiary treatment or effluent polishing is used to further improve effluent quality of secondary effluent. In Ontario the only effluent polishing techniques employed for municipal wastes are polishing lagoons and tertiary filtration.

Polishing lagoons are inexpensive but require a large tract of land. The secondary effluent is passed into the lagoons and retained for several days allowing extended removal of BOD and SS. Growth of bacteria and algae is encouraged to aid in the oxidation of organic wastes.

The second method employs sand filters and is the most widely used. This technique allows a high removal of BOD and SS with significant nitrogen removal.

Phosphorus Removal

Phosphorus in all sewage treatment plants in the lower Great Lakes basin must be reduced to 1 mg/l. Aluminum or iron salts are introduced to precipitate phosphorus from the effluent. Additional organic matter is precipitated with phosphorus in further removal and reduction of SS in primary treatment plants.

The above general outline of sewage treatment practices employed in Southern Ontario may be applied to facilities discussed in this report, with a more detailed outline presented in a report by the Ministry Of The Environment (MOE,1980)

	DATE DUE		